SELECTIONS

FROM THE

RECORDS OF GOVERNMENT,

NORTH WESTERN PROVINCES.

VOLUME II.

1853.

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PREFACE.

The earlier numbers of the SELECTIONS FROM THE RECORDS OF THE GOVERNMENT, North Western Provinces, having become out of print, and it being necessary to publish a new Edition, the opportunity has been taken to re-arrange and classify the articles according to their different subjects.

Articles under the following heads were included in the First volume:—

I.—JUDICIAL.
II.—FISCAL.
III.—STATISTICAL AND MISCELLANEOUS.

The Second volume contains articles under the heads—

I.—IRRIGATION.
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The series comprehends all the articles published up to the end of 1853.

SELECTIONS

FROM THE

RECORDS OF GOVERNMENT.

PART I.

IRRIGATION REPORTS AND MAPS OF THE PRESIDENCY OF MADRAS;

FORWARDED BY THE SECRETARY OF THE BOARD OF REVENUE, MADRAS.

No. 1.—*From* CAPTAIN S. BEST, *Secretary to the Board of Revenue, in the Department of Public Works, to* R. CLERK, ESQ., *Acting Chief Secretary to Government, No. 521, Madras, 28th October 1842.*

SIR,

With reference to the concluding paragraph of the Memorandum which accompanied my letter of the 8th ultimo, I have now the honor, by desire of the Board of Revenue, to forward the copy of Major H. C. Cotton's memoir* on the irrigation of the Province of Tanjore, together with additional plans connected with the subject.

NOTES ON THE 5TH DIVISION,

BY MAJOR H. C. COTTON, *Acting Civil Engineer.*

It is impossible to become acquainted with the Province of Tanjore, without viewing with admiration and wonder, the degree of perfection to which the irrigation was brought before even the British possession of the country, and indeed before the date of any existing record. The main branches of the Cauvery, with the branch that retains the parent name, the minor channels separating from those, and the innumerable ramifications threading the whole surface of the Delta are so disposed, that one can scarcely believe that it was a gradual work, each portion the accidental result of what had been before done, but the work of consummate skill and science planning the whole system at once, and establishing it.

* Dated 10th March.

Changes have taken place during the last 40 or 50 years, disordering in some measure the irrigation of certain tracts, and remedies have been of late years applied, but these have been almost entirely confined to restoring those tracts to the condition they had been in at some former period. But viewing the system generally, we find the levels of the main branches perfectly well adapted to supply the smaller, and these to distribute again the water to the lands, apparently with the least possible waste of labor in the excavation of channels, the least multiplication of sluices and aqueducts, to give the supply the different levels required, and the most convenient distribution to the various villages and farms, while the drainage of all is at the same time most admirably provided for.

The difficulty of obtaining a full supply of water in the Cauvery or southern main branch for the irrigation of all Tanjore has been the grievance of ages; Colonel Caldwell imputed it to the beds being so raised by the accumulations of sand from the Colleroon head to the sea, as to turn the water into the course of the latter river, and declared his opinion that though temporary measures might improve the supply, nothing but opening the mouth of the Cauvery, and forcing a great body of water by that course to the sea, could carry off the continual influx and accumulations of sand, and therefore nothing else could keep the beds on a sufficiently low level to ensure a supply of water; and he anticipated that in not many years, the rivers would be dry, and the country ruined. This was I believe in 1803: he raised the grand Annicut where the bed was high, and where, in consequence, great part of the water escaped to the Colleroon. This was the first improvement, but it was temporary; the supply fell off, and an opening about two miles from the present head of the Colleroon, through which a great body of water passed back to the Colleroon, was closed, thus throwing the separation of the rivers further west, and taking advantage for the moment of the deep channel then forming the head of the Cauvery. This was soon found to be a mere temporary improvement; the deep channel filled with sand, and the river was as badly supplied as ever. This was the second attempt, partially successful for a time, but not at all rising above the fears and anticipations of Colonel Caldwell. His prophecy was growing more fearful, and its realization apparently more near at hand. It was then proposed to make sluices in the bank between the Cauvery and Colleroon, for the purpose of discharging surplus water, with a view to clear the Cauvery in a measure of its accumulating sands. This was the third experiment, or rather the third improvement, for they were all such in a greater or less degree, and this was decidedly a radical and permanent one, leading to no harm, because an agent under command, to be employed when, and in whatever degree desired; and to a certain extent, as I shall show, beneficial to the river at the time, and still more so eventually.

The river bed, at the grand Annicut and below that, was much lowered, but near the head, where the other set of sluices are, no change was effected, because the two rivers being so nearly on a level at that spot, there was no strength of current through those sluices, and no sand discharged. The supply of the river fell off again, and with yearly increasing rapidity; and in 1835, there was so great a difficulty towards the close of the season to draw by means of a Corumboo any water into the Cauvery, that in all probability the next season would have been as nearly as possible what Colonel Caldwell had prophesied. But here I must remark that the evil, though the same, was not by any means from the same cause as that on which he grounded his prophecy. Had the bed of the Cauvery been ever so wide and deep, towards its mouth, this evil

would not have been averted; the supply could not, in the slightest degree, be affected by it; for suppose the bed of a river to be raised 15 feet at a distance of 60 miles from its source, and suppose the fall in those 60 miles to be 135 feet, and to be thus reduced to 120 feet, the diminution of supply would be 1-18th only, and such a change is beyond, what has I believe any where taken place in the course of ages; the beds of many of the rivers no doubt rise gradually, when not well supplied with water in high freshes, or when altogether without vent, but that is comparatively a very trifling and remote evil as affecting its supply, and in like manner the deepening of the extremities would be but a trifling and remote improvement: as long as the parent channel continues deeper, or has a greater fall than the branch at the point of separation, the branch suffers from the formation of sand banks at its head; this is always the case in all the channels, small and great, and this has been the great cause of failure in the Cauvery itself, and has rapidly followed every improvement of the river which left the Colleroon still the deepest channel at the point of separation, as well as with a greater fall. The raising of the bed of the river originally established an elevation above the bed of the Colleroon, and this no doubt must be considered the primary, though not the immediate, cause of the evil, and none of the former improvements tended to counteract it; but the same cause remaining, the same effect ensued, whether that cause increased or diminished. So likewise the deepening of the lower parts is a primary step to the restoration of the original level and fall of the river, but this can never amount to the fall of the Colleroon, which takes a shorter course to the sea, and therefore never can remove the evil entirely. Here therefore is the reason that the under sluices alone could not prevent the closing of the head of the river, though they deepened the bed for many miles of its course. All of them being too far from the head to affect it at all, except the first set, which, till the Annicut was built, had no sufficient fall.

The river, as I stated above, was deepened at a distance of 20 miles from its head by the use of the several sets of sluices, and there was ample capacity at the grand Annicut for a full supply of water, if it could have been brought there, but the head itself was choked with accumulations of sand, and the supply diminished in proportion.

It is very remarkable that the beds of the rivers generally do not appear to have risen since the period of Colonel Caldwell's report. No accurate observations have been taken to prove this, but I can discover no grounds whatever for supposing that they have risen. One proof of this fact is, that the rocky bed of the Vennaur, 8 miles from its head, is bare rock still, and as far as is known, this part of the river, which would so plainly show a change, is in the same state as it was 50 years ago. Another proof is, that of all the channels which fall into the rivers, for the drainage of the land, none that I can discover have ever become choked by the rising of the bed of the rivers. I feel convinced that the outlets for the sand, (through which, during high freshes and during the heavy local rains, much water escapes to the sea) have been nearly, if not quite sufficient to prevent any such rising of the beds as Colonel Caldwell anticipated, and on which his prophecy of the ruin of Tanjore was grounded. The grand Annicut certainly required to be raised, to accord with the then state of the river-bed, and it was there, no doubt, that much of the supply of water was lost; but I feel convinced that even at that time the head of the river was the main seat of the evil. Much money was expended from time to time in deepening the head, and raising temporary Corumboos, as well as on the great work of closing, what was called, the Govinda Calagum,

above referred to, and by these means the battle was fought inch by inch, but it was after all a retreat before an overpowering enemy, delaying the conquest, but without a prospect of victory, until the weaker party was joined by a strong ally, and an entirely new arm was brought into the field. This new and most opportune work was the upper Colleroon Annicut, projected by Captain A. T. Cotton, after much study and experience, the effect of which has been found perfect; giving the Cauvery its full supply of water as long as there is so much in the entire river above, and giving such power to the upper (or 20-vent) sluices in the Cauvery bank, as to keep the head of the river permanently deeper than that of the Colleroon, and therefore the first of the two rivers to be supplied in times of scarcity.

The Annicut alone would have unfailingly supplied the Cauvery with its water, and the head would never, I think, have been liable to close up as before, but in combination with the sluices, it gives a perfect command over the bed of the river, which is an advantage scarcely within the view of those who most deeply studied the project; had Colonel Caldwell's project of deepening the river towards the sea been effected, and as he anticipated from it, the whole river deepened throughout its course, what would have been the consequence. The whole system of the irrigation of the district would have been disordered. The lowering of the beds, which now command the lands, would have caused the branch channels to require dams everywhere, to raise the water to them, or new branches from a distance above those which now supply the fields would have been required, while the head of the river, totally uninfluenced, would have continued as it has done to close with sand, and the supply of the river to fall off.

The upper Colleroon Annicut was built in 1836, and there were at that time four sets of sluices in the Cauvery bank for the discharge of sand, viz. the 20-vent sluices 2 miles, the Vuddavagoody sluices about 35 miles, and the Permaul Coil 50 miles from the head of the Colleroon. These were kept in use when water could be spared during the five first seasons, and from all that could be discovered (by no very accurate observations) the river beds had rather deepened than otherwise, but certainly no very important change had taken place. In consequence of some alarms being expressed as to the effect of the Annicut in throwing into the river more sand than could be discharged, I thought it desirable to make as good a trial as possible of the season of 1841, by not opening the sluices of the Grand Annicut and those to the eastward; and the long continuance of the high freshes has made the season one especially well calculated to give the river an unusually great influx of sand, while the monsoon being very light, the lower parts of the river did not receive the cleansing which a heavy monsoon ensures, the local rains having the effect of discharging vast accumulations of sand into the sea, while they introduce none. Still the sections taken show no increase of sand, but rather a decrease. Accompanying my report of 9th March 1842, is a set of sections shewing the changes in the bed of the river during the season, and with one or two exceptions, out of 40 sections, the bed is lower at the close of the season than before.

A considerable change has in the course of the six seasons taken place at the separation of the Cauvery and Colleroon. The deep channel of the main river was along the north side leading down into the Colleroon, the south side being raised with sand banks, and the head of the Cauvery itself choked up with them. The effect of the Annicut was to throw a strong stream directly across the head of Seringham, sweeping out a very deep channel of no considerable mass of sand, and opening the head of the Cauvery during the season. The Cauvery was then

secure of a full supply of water, as long as the main river could furnish it, and though there was an unheard-of scarcity of water in the main river that year, the crops throughout Tanjore were tolerably abundant. There can be no doubt, had the Annicut not been built, that every year the loss would have been incalculable, and in the 2nd, 3rd and 4th years, the south-west monsoon was also exceedingly light, and the river very scantily supplied, so that the benefit of the Annicut was in fact felt to a degree which no foresight could possibly have anticipated, but which making no very palpable appearance in the revenue accounts, unsupported by the consideration of the deficient supply of water in the main river, has not earned for the work that credit, which its immense effect gained, where the circumstances were all known. The revenue of Tanjore being so materially affected by the varying price of grain, makes it difficult to show distinctly the benefit the district has derived from the Annicut, but the price of land gives a very remarkable proof of its effect, and to show the feelings of the people most interested, and best able to judge of the actual advantage derived from the Annicut, I need only to repeat what has been often said to me, that at the expense of one rupee per vaily of land, the work could be built at the expense of the people, *annually* (if necessary) with immense profit to them, quite independently of the increase of revenue obtained by Government; and these remarks have been backed by an offer of one rupee per vaily from the landholders under the Vennaur, if the Government would build an Annicut across the Cauvery at its head: a sum of about 30,000 rupees.

Since the construction of the Colleroon Annicuts, they have been annually improved and strengthened, and are now brought to the condition of good permanent works, not only well-fitted for the purpose for which they were constructed, but requiring very trifling annual repairs. The centre branch of the upper Annicut was lowered last year; its present height 4½ feet being sufficient to throw into the Cauvery a full supply of water for all Tanjore. The lower Annicut is now to be raised four inches, and covered with cut stone, which seems to be at present all that work requires. The raising is chiefly intended to add to the supply of the Vuddavaur and Veeranum for the benefit of the lands on the north side of the Vellaur river, across which an Annicut is proposed to be constructed. The lands irrigated by the lower Annicut are the talooks of Mannargoody and Chellumbrum in south Arcot, and a considerable tract of country along the south bank of the Colleroon extending to the sea.

The 20-vent sluices have been greatly improved by the enlarging of the vents; they now discharge a great body of water in high freshes, and of course also a great volume of sand, and are, I think, in plan as well as in effect, an excellent work: this is the first outlet from the Cauvery to the Colleroon. They have been strengthened by rough stone defences, and seem to be very secure.

The 150-yard Calingulah is the next outlet for flood water, and by this a considerable quantity of sand also escapes. The work has no solid apron, but one of loose stones, which has been annually improved by the addition of rough stone, and the whole work is now in good order. A foot bridge was constructed on the crown of it in 1838.

The grand Annicut is the third outlet. It has 350 yards gorge, and 10 vents through its base, and the fall between the two rivers being here considerable, the discharge, both of sand and water, is very great.

On the shapeless body of this ancient work is a bridge of 30 arches, of 30 feet each, constructed in 1838, and an extremely useful communication.

The Coiladdy Calingulah of 100 yards gorge, and still greater fall than that at the grand Annicut, is the fourth outlet, and has an immense effect on the floods of the river, discharging in the highest freshes about half the water that reaches that point, with much sand also. A low apron was added to this work last year, and it is now in good order, but it would be the better for a covering of cut stone. The bridge over the Calingulah makes it a very complete work.

The Vuddavagoody sluice is the fifth outlet; it has 12 vents, and is a low work discharging water over it in the floods (having been lowered four feet since its construction.) The body is of great thickness, and contains a considerable mass of cut stone work and brick masonry that might have been dispensed with, without diminishing its strength; a low apron was found necessary to secure the foundations, and was added last year.

The Permaul Coil sluice is the sixth and last point of discharge for the flood waters of the Cauvery; it has 6 vents. The water passing out by this sluice falls into the Munnyaur, and is discharged from that channel by another sluice into the Colleroon. This arrangement limits the use of this sluice, and I think it would be very desirable to carry the water from it under the Munnyaur direct to the Colleroon. It might then be used freely for the discharge of water in times of flood, as well as for sand, for which alone it was intended. It would be necessary to carry the Munnyaur by an aqueduct over the channel leading from the sluice to the Colleroon on account of the navigation, and on this account also a new channel would be required from the Permaul Coil lock to the Munnyaur.

Previous to the construction of the Colleroon Annicuts, much pains were taken so to regulate the distribution of water as to give a fair proportion to each main branch, and several important works were constructed for the purpose; and although the abundance of the total supply for the district has rendered this a less important consideration, it still requires attention. The Vennaur river, which is the first main branch, has always been ill supplied in comparison with other branches. Some improvement has been made in the last two years to its head, and this improvement is still going on, and I think with the promise of considerable effect. It has a second head, affording it some help in low freshes, and I think it very desirable that a third should be opened from the Cauvery, either opposite Coiladdy, to fall into the river immediately below the Cutchamungalum Annicut, or about three miles from the head immediately below the grand Annicut.

One or other of these projects, both of which have been fully investigated, should I think be taken into consideration, if it is found that the improved form of the head of the river does not fully answer the purpose of giving it a due share of the whole supply of water.

The Codamoorty, which is the second great branch, was formerly ill supplied also, compared with the parent river, but a favorable change has taken place in its bed, and it is now deeper than the Cauvery. An Annicut across the Cauvery for its benefit was recommended four years ago, and obtained the sanction of Government, but it has not been found necessary to construct it.

The Arasalaur is the third great branch from the Cauvery. It has also a head in the Trimulrojen, which is a branch of the Codamoorty. This channel has been greatly improved of late by a new open head from the Cauvery; which indeed it had originally, but owing, it seems, to its drawing too much from the Cauvery, it was closed many years ago. The river in 1836 was entirely dependent on the Trimulrojen, and a head, with a limited sluice, was formed for it in the

Cauvery: this being still found insufficient, the new head, without a sluice, was opened two years ago. This head is now becoming too great, and another change will shortly be necessary; either merely closing the present opening, and cutting one lower down, or reverting to the use of the head sluice.

The state of the Tritrapoondy Talook in Tanjore now calls for much of the attention of the Civil Engineer; I have made a general report on its condition, and sent to the Board two projects for its improvement, but there is a vast deal more to be done, and there is no part of the 5th division now, where a considerable outlay would make so great a return.

In the Trichinopoly district some improvements have of late years taken place, and others have been projected, but have not received the support of the Board. There is a wide field for extending cultivation in the Talooks north of the Colleroon. The waters of the Vellaur, and several copious Jungle streams, might be made to yield revenue by irrigating these tracts.

The improvement of the Wyacondam channel branching from the south bank of the Cauvery has been long in contemplation, but with many other equally important subjects is deferred until the Civil Engineer's time is available for it, or till he has the assistance of other officers.

In the Talooks of Manargoody and Chellumbrum in south Arcot very extensive improvement has been made. Channels have been laid out over a great tract of waste land, and the Vuddavaur, which is the main channel, has been widened, and the whole being supplied by means of the lower Colleroon Annicut, they never fail; a great deal also has been done for the distribution of the water to the old cultivation, and with these improvements in the irrigation, a system has been planned, and to some extent carried out of the drainage of the Talooks, so that the whole state of the cultivation is in a condition to advance rapidly; but it is unhappily checked by the low prices of grains, the consequent poverty of the people, and the want of some considerable change in the laws affecting the tenure of the land, and encouragement to those who are willing to cultivate.

A line of navigation has been established from the Cauvery across the Colleroon, and through Manargoody and Chellumbrum to Porto Novo. This most valuable project obtained the sanction of the Supreme Government almost two years ago, and it is now nearly completed. The traffic from Coimbatore and Salem formerly went down the Colleroon direct to the sea, but since the construction of the Colleroon Annicuts, that river is seldom navigable for more than two or three days at a time, and usually only at one period in the month of July, when the freshes are at the greatest height. To remedy this serious loss to the mercantile community, this new line has been established. Its course is down the Cauvery, and uniting with the Trichinopoly trade, it follows the course of that river to Permaul Coil, about 40 miles below Trichinopoly, where a lock of 9 feet fall with a regulating basin for the highest rise of the river, has been constructed for the descent into the Munnyaur, an irrigating stream branching from the Colleroon. The navigation then takes the course of this stream to Tripendaul, a distance of 25 miles, where a level canal, two miles in length, communicates with the Colleroon immediately above the lower Annicut. This canal has a regulating lock at the upper end, and a lock of nine feet fall into the Colleroon at the other extremity. Crossing the Colleroon into the Vuddavaur, and pursuing the course of that channel to the great Veeranum tank at Laulpett, another descent is met with, which is obtained by a lock allowing for seven feet fall, besides the varying height of water in the tank. From this a short canal of half a mile, with a lock to two falls of seven feet at its lower

extremity, gives a descent into the Vellicul; a deep surplus channel falling into Cawn Saib's channel, at the distance of three miles below Laulpett; after which there is no lock till the mouth of the Vellaur is reached, where a lock of six feet fall provides for the descent to the level of the sea. The Cauvery is navigable from Trichinopoly to Permaul Coil, with some intermissions from June till December, and the remainder of the line remains open sometimes till February. The streams are moderate in velocity, and far down, traffic exceedingly easy and convenient. The locks are built for barges 48 feet in length, by 12 in breadth, and drawing 4 feet of water, or 4 basket boats of 12 feet diameter. It would be difficult and expensive to make good towing paths on this line, and in the Cauvery it is of course impracticable; it would therefore be exceedingly desirable to use steam for ascending, and if this were introduced, I have no doubt the line would be crowded up and down with merchandize and Government stores, troops and passengers of all descriptions: barges should be built to fit the locks and steam-tug vessels of moderate power, to take them up from the coast to Trichinopoly. The long-talked-of coast canal, or sea-going steamers, would complete the line from the Presidency.

Many bridges have been built in Tanjore within the last six years, the most important of which are the Vellaur bridge at Nagore, 12 arches of 30 feet span, and the Vennaur at Tanjore, 5 arches of 58 feet each, and besides these, about 20 bridges of from 30 feet to 150 feet water-way. These, with many smaller tunnels, complete several most useful lines of road through a country hitherto locked up during about eight months in the year from any possible communication through it, except in one or two main lines of road. It has always been my study, if possible, so to construct irrigation works, as that they may afford communication over the streams on which they are built, and this has tended also to open roads, and render accessible towns and villages to which there had previously been no approach during the cultivating season.

I have also endeavoured to make the river and minor channel embankments passable roads, not only for the convenience of the public, but that they may be well examined and kept in order. I have no doubt that attention to these points has been of great general benefit to the country, not merely at no expense to the Government, but preventing many accidents, and thereby saving much in the repair of breaches. The bridges have been always designed on the most economical principles consistent with stability. I have studiously avoided all ornament, and adopted arches seldom exceeding 30 feet span, which are easily managed, and are done with almost the least comparative quantity of masonry. The whole population of the district is alive to the benefit they have derived from these communications, and I am sure I utter the unanimous voice of the whole district, when I say, that stopping the expenditure of the surplus Davastanum funds in this way has been a severe disappointment, and that if put to the vote, every hand would be held up for the disposal of these funds in the construction of bridges and other works for the public good. The funds do not belong to Government, and the Government desires not to appropriate them to State purposes; they belong to no individuals or particular communities, and few, if any individuals, are found willing to take upon themselves the charge of them with the Pagodas; they belong to the people, and the people are willing and anxious that they should be laid out in this way, and undoubtedly the indirect benefit, which the State would obtain from the improved communications, would be great, while the energies of the people would be diverted from their extravagant ceremonies, to the promotion of works of usefulness. The proposed

bridge over the Cauvery at Trichinopoly is one of the most desirable works in this part of the country. It was planned and estimated six years ago, and was approved and sanctioned by the Court of Directors, but has never been built. The Pagoda funds might well be employed in this work, and whether the welfare of the people, the wish of the East India Company, the interest of the State, the whims, fancies, or rational desires of every caste and class of the people are consulted, they must be so disposed of; one and all of these will most assuredly agree that they can be applied to no more satisfactory purpose. I have carefully planned the bridge, marked out what I consider the best site for it, and I trust the work will yet be undertaken.

J. H. BELL.

UPPER COLEROON ANNICUT,
The 10th March 1842.

No. II.—*Extract from the proceedings of the Board of Revenue, in the Department of Public Works, No. 191 B., under date the 25th April 1842.*

In obedience to the orders of Government contained in the Minutes of Consultation, dated 17th March 1842, the Board proceed to take into consideration the correspondence which accompanied it.

The subject, on which the Military Board of the Bengal Presidency request information, may be said to embrace the whole science of irrigation as practised in the Madras Territories, while the reports called for can hardly be supplied without, not only a careful examination and selection of the masses of papers and plans that exist in the records of the Department of Public Works at the Presidency and of the eight Civil Engineers, but the preparation of new plans and the taking of new series of levels and surveys in order to supply materials capable of being put together in a compact form, and which might serve as a basis for the guidance of persons unacquainted with the nature of the works, it is now proposed to imitate in the Bengal Provinces.

There can be no doubt that such a digest would be generally useful, but it would be a work of some labour and time, and, unwilling to delay replying to the orders of Government until it shall be completed, the Board instruct their Secretary to select such plans and reports as appear likely to afford most of the desired information, and at the same time to submit in a few paragraphs a general explanation of the nature of the artificial means in use in the Madras Presidency for the purpose of securing water during the dry season to sustain the irrigation of rice lands.

No. III.—*From* CAPTAIN S. BEST, *Secretary to the Board of Revenue, Department of Public Works, to* R. CLERK, ESQ., *Acting Chief Secretary to Government, No. 442, Department of Public Works, Madras, the 8th September 1842.*

SIR,

Paragraph 1.—I am directed by the Board of Revenue to acknowledge the receipt of the extract from the Minutes of Consultation, dated the 17th of last March, transmitting an application from the Bengal Military Board for information respecting the system of irrigation pursued under this Presidency.

2.—With the view of supplying the required information, the accompanying memorandum has been prepared, which, with the plans and notes intended to illustrate the subject, will, it is hoped, prove of some service to the Bengal Authorities in any projects which they may propose to undertake to extend and improve the agriculture of that Presidency.

1 Memorandum.

3.—The Revenue Board is aware that the report is incomplete, and that it may not be found to convey satisfactory information on all the topics embraced in the letter from the Bengal Board, and indeed it is impossible without much and direct communication to make so comprehensive and intricate a subject as the system of irrigation at this Presidency intelligible to those who have not had an opportunity of witnessing and examining it. More details and plans will however be supplied as they can be collected and digested, and the Board will always be ready to explain more fully any parts of the system which are not clearly comprehended. They will also be happy to give their best consideration to any special plans or projects for the establishment of works of irrigation, on which the Bengal Authorities may wish for their opinion, and it is possible that the interests of both Presidencies may be advanced by a free interchange of opinions and experience.

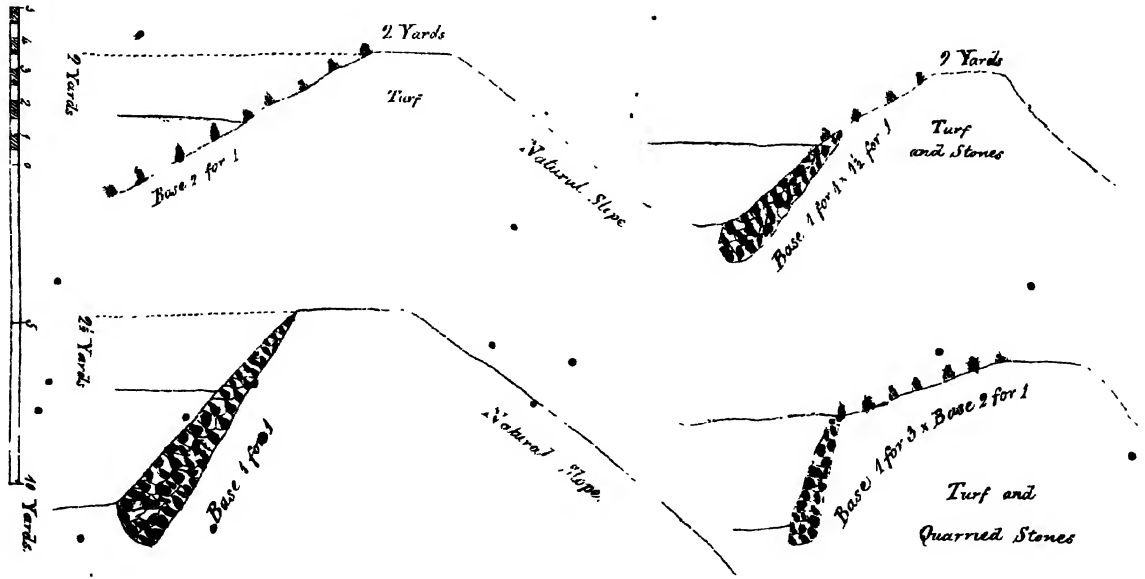
4.—To save unnecessary trouble to both Governments, it may be convenient to place the Bengal Military Board in direct communication with the Revenue and Military Boards at this Presidency on questions connected with irrigation.

5.—I am directed to take this opportunity of stating that the information applied for by the Bombay Government is now under preparation, and will be afforded at an early period.

No. IV.—*Memorandum on the system of irrigation in the Madras Presidency, by* S. Best, *Secretary to the Board of Revenue, in the Department of Public Works.*

1.—The simplest and most usual description of work is the Tank. This is formed by raising across the upper part of a valley an embankment, by means of which water supplied by the periodical rains, by jungle streams, or by river channels, is collected and retained for irrigation the lands, and bringing the crops to maturity during the hot months. The fields occupying the lower part of the valley are watered from the tank through sluices of irrigation erected in its bank.

2.—The banks of the generality of tanks seldom exceed five yards in height. Many of them are formed of earth only, in a few instances carefully turfed; while some of the larger works, and in country where stone is abundant, many of the smaller banks also, are protected by loose blocks of rough stone laid on the inner sloping surface or disposed in the form of a nearly upright revetment without mortar or cement. The object of these rough stone facings is not so much to support the earth work as to protect it from the action of the waves during stormy weather, and from damage by the monsoon rains. [*Vide plans*]. Many tanks are often formed in the same valley, the bed of one sometimes beginning where the cultivation under that above it ceases. In consequence of this the breaching of one tank often leads by the sudden influx of its waters to the bursting in succession of those below it. This is more particularly the case when heavy and sudden rains succeed seasons of drought, during which the earth of which the tank banks are composed loses tenacity and is soon saturated by water. Another and the general cause of the breaching of tanks is the


9 Yards
2 Yards
Turf
Base 2 for 1
Natural Slope
9 Yards
Turf
and Stones
Base 1 for 1 x 1½ for 1
2½ Yards
Base 1 for 1
Natural Slope
Base 1 for 3 x Base 2 for 1
Turf and
Quarried Stones

neglected state of their banks which are not in all parts sufficiently raised above the surface of the water in them. High winds exciting waves in the tank, throw the spray over the lowest parts of the banks which are thus gradually worn away until at last the water overtops them and a breach ensues.

3.—In order to provide for the outflow of such water as may enter the tank after it has been received as much as the state of its banks enables it safely to hold, portions of the bank (generally at one or both extremities and frequently across the bed of the jungle stream by which the water arrives) are formed of masonry, the height of which is so regulated as to allow the surplus water to pass over, and their lengths which vary from 5 to 200 and 300 yards, by the size of the tanks and the quantity of water which they receive during floods and the monsoon rains. Works of this nature are generally known in this Presidency by the name CALINGULAH, a Tamil word of originally much wider import. Along the upper surface of these, a row of upright stones 2 to 4 feet apart and from 2 to 8 feet high are generally inserted. The interstices between these stones are filled up with earth, straw and rubbish to increase the capacity of the tank when the rains are moderate, but when the supply of water is too great, and the tank is in danger of being breached, the interstices are cleared to allow a large quantity of water to escape, the rapidity of the outflow being increased by the additional vent thus afforded. The dam stones are made of such height that the top of the temporary bank raised between them is nearly on the level to which water can rise in the tank without endangering its bank. In some tanks, the excess of water flows out from vents pierced at a low level in masonry walls similarly placed. These vents are closed by vertical planks inserted side by side or by shutters. Works of this description termed SURPLUS SLUICES allowing the water to flow out with greater rapidity are of smaller dimensions and less expensive than Calingulahs. They have also the very great advantage of permitting the escape of mud and sand from the bed of the tank, by the accumulation of which all such works are otherwise liable, in the course of time, to be filled up and rendered useless. Vents to be closed by planks or shutters have frequently been constructed in the lower part of the body of Calingulahs. But the common Calingulah is the usual way of allowing the surplus water of tanks to escape.

4.—Sluices of irrigation consists of long tunnels of cemented brick or stone, arched or covered with flat stones, passing through the banks of tanks and on a level with the bed of the tank—furnished at the extremity inside the tank with a contrivance for regulating the quantity of water that flows to the fields, and at the other end with a cistern or basin, the walls of which are pierced with holes at different levels through which water running to the branch channels is carried to fields at various elevations. The sluices in large tanks have sometimes cisterns at the inner end also, the object of which is to prevent the accumulation of mud at the head of the sluice. The ordinary contrivance at the head of the sluices known by the name of payal, consists in a vertical door (often merely a block of stone) which is removed to allow water to flow, only when the tank is nearly empty, and in a portion of the covering (which is of stone) being pierced with a conical hole in which a conical block of wood attached to a long bamboo is moved upwards or downwards from a frame of two large upright stones, and two or three placed transversely for the sluice man to stand on. These latter have holes in them through which the bamboo is lifted or lowered. The orifice, through which the water issues, is blocked by this description of stopple or opened to any desirable extent according to the demand for water.

5.—Irrigation by tanks is often combined with that by rivers, the water from the rivers being brought into tanks that are favorably situated by means of channels cut through the river bank and intervening ground.

6.—Irrigation from rivers requires for more scientific knowledge and enquiry than irrigation by means of tanks only, such as is above described. It is easy to judge of the possibility of retaining water by stopping the course of the natural drainage or of jungle streams of moderate dimensions, but to decide on the possibility of partially diverting the waters of rivers into entirely new courses, and on the positions that these new courses should occupy, so as with the least expense of excavation to obtain the greatest and most constant supply of water, requires not only a just appreciation of the difficulties of digging in soils of varying hardness and to varying depths, but the taking of accurate sections on different lines, by which to ascertain the relative levels and the fall that can be allowed to the beds of the proposed CHANNELS, in short a knowledge of the form of the ground both accurate and comprehensive.

7.—A plain which it is desirable to irrigate can hardly be so situated, but that the bed of a neighbouring river is at some part or other of its course relatively higher in level. Supposing* a surface A. B. to slope from A. to B. at the rate of two feet in a mile and to be traversed by a river C. D., the bed of which falls at the same rate, but is throughout 20 feet below its banks; it is evident that the part of the slope, which is 10 miles from A. towards B., will be on the same level as C., and that were a channel C. E. excavated with a horizontal bed, water from the river above C. would flow along it until it reached E., whence it might be conducted to irrigate the lower portions of the slope E. B.

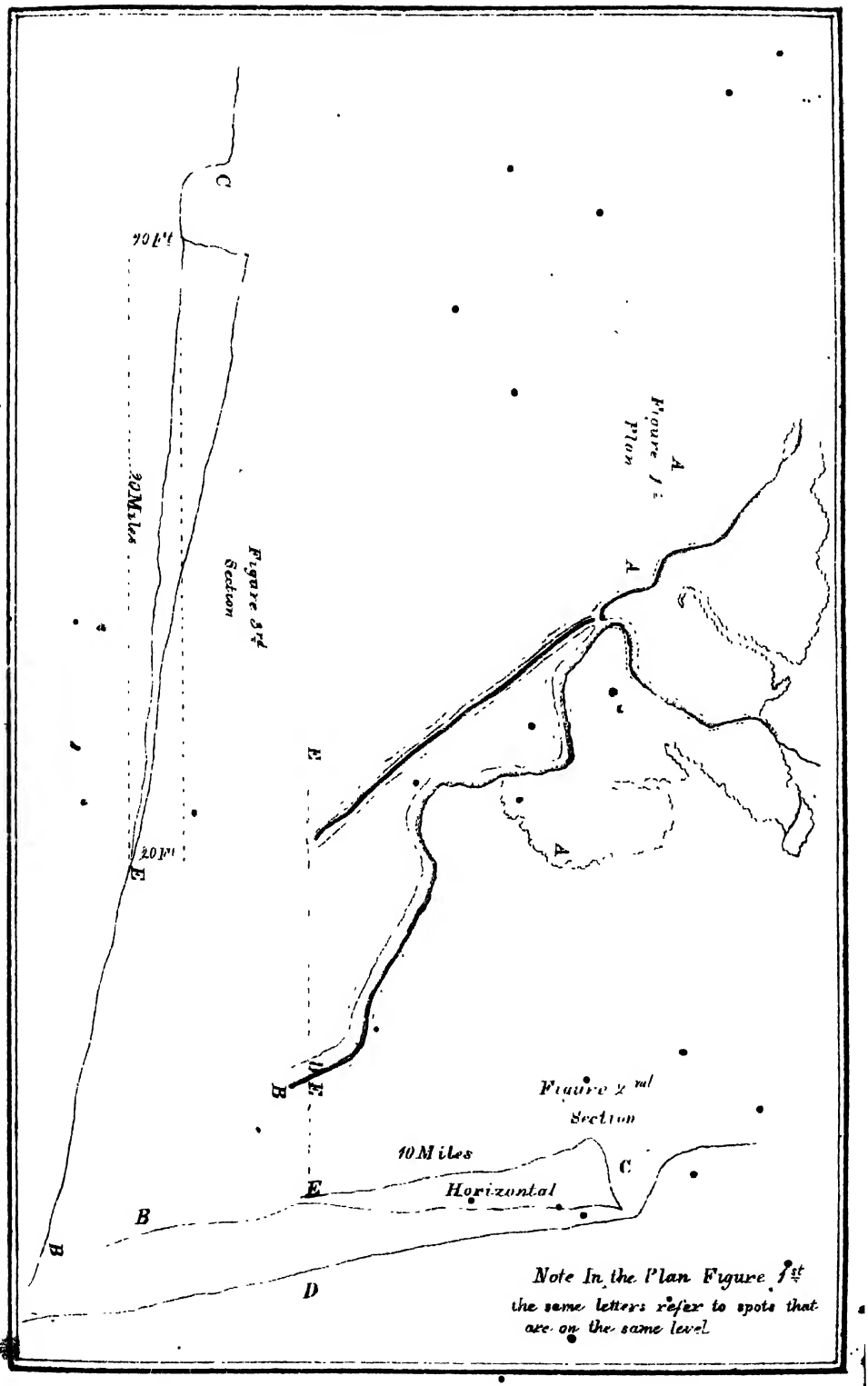
8.—In like manner, if the bed of the channel were made to fall one foot per mile, it would at 10 miles be only 10 feet below the country; and at 20 miles, having gained a foot per mile, it would emerge on its surface.

9.—The case is more unfavourable, but still similar though the country should also slope, as it most frequently does, towards the river as well as towards the sea. In this case the water to the lands farthest from the river must be brought from a part of the bed nearer to its sources, and the excavations must be deeper, or, as it will often happen, the expense bearing too high a ratio to the attainable advantage, the irrigation must be restricted to those lands which lie nearest to the course of the river and at the lowest levels.

10.—CHANNELS of irrigation have been taken off rivers such as the Palaur in Arcot, the fall of the bed of which is at the rate of nearly 10 feet in a mile, and its ill-defined banks 6 to 8 feet high, as well as from such as the Kistna which runs with a fall of less than one foot per mile and between steep banks of 35 feet.

11.—It is the relative fall of the river, and of the country on its banks which determines the least length which the channel can have in order that its bed should emerge above the surface and its water be brought to use, but when the freshes are of short duration and channels are led to tanks, it is evidently desirable, in order that they should deliver water rapidly that they should be wide, and the velocity of water in them considerable; although to afford slope to their beds their length should be extended, and the expense of excavation increased. Six or eight yards may be considered the greatest depth to which irrigating channels have yet been excavated in this Presidency; but the general average is not more than two or three yards. Great

* Fig. 1. 2.


C
20 Miles
Figure 3rd
Section
E
20 Miles
E
B
A
Figure 1st
Plan
A
A
Figure 2nd
Section
10 Miles
C
E
Horizontal
B
B
D
Note In the Plan Figure 1st
the same letters refer to spots that
are on the same level

portions of some channels have been formed by throwing up one bank only on the lower side of a slope; thus, (Fig. 3.)

Figure 3rd.

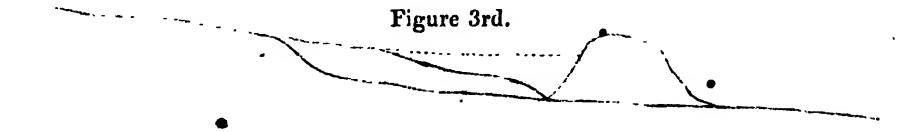
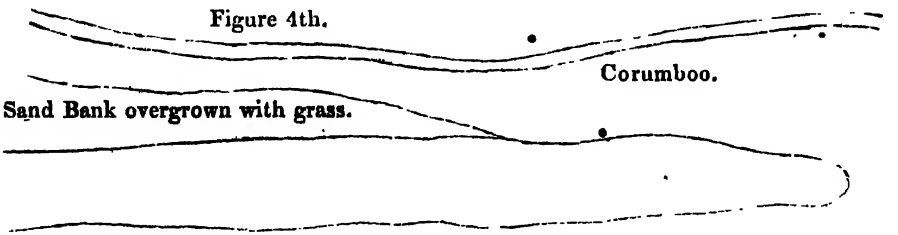


Figure 4th.



And the heads of some river channels by separating part of the bed of the main stream by means of an artificial bank, (Fig. 4.) protected by river grasses, &c.

12.—In some cases, these artificial banks are carried for very considerable distances up the rivers or obliquely across their sandy beds.

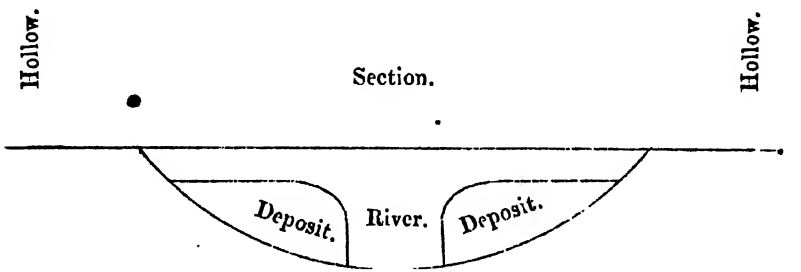
13.—Such banks termed Corumboo are generally over-topped and carried away by all freshes of more than 1½ yard depth of water. They are temporary expedients or substitutes for permanent dams or Annicuts, to turn the early and low freshes of rivers into irrigating or tank channels, and being liable to be partially and sometimes entirely destroyed by every full fresh, require to be repeatedly repaired and occasionally re-constructed during every season. They are usually constructed and kept in repair by the proprietors of the land which they irrigate without any cost to Government.

14.—In the Kistna and Godavery banks, the channels not having been excavated to more than 15 feet depth* no water enters them until those rivers are partially filled, and the lands do not receive water from them, excepting during the season of freshes or for about four months of the year.

* The bed of the river being 30 feet below the banks.

15.—In such cases when the bed of the channel at the head is not made as deep as that of the river, it may as well be horizontal, for to obtain some water during a longer period by having the head of a channel deep is more desirable than to sacrifice this advantage for the purpose of obtaining increased velocity by giving slope to the bed, in fact, the velocity depends not upon the slope of the bed but upon that of the surface, and these are rarely the same in channels such as those of irrigation which are seldom or never uniform in depth or dimensions, in direction or in any other respects. The interior of the Masulipatam district south-east of a line drawn from Bezwara through Ellore and Rajamundry is in great part lower in level than the beds of rivers at the points crossed by the same line, and might be irrigated from these rivers even when their waters are lowest, if channels were cut of sufficient depth through the ground which slopes from their borders. The slope begins with a fall of 4 feet a mile, but is gradually reduced in approaching the Colair Lake, a shallow basin that occupies the centra of plains almost flat, and from 6 to 12 feet only above low water in the neighbouring sea.

16.—The extreme depth of such channels would be for the Kistna 35 feet and for the Godavery 25 feet; but it must be noticed that the channels now in existence (and the depth of which, below the country at their heads, nowhere exceeds 15 feet) are liable to be partly blocked by deposits of sand which require to be annually removed. The velocity of these rivers being at the freshes about 5 miles per hour, even their *upper* water is then mixed with large quantities of earth and sand, which, being brought into the channels with the water are deposited chiefly in their beds as the velocity gradually decreases. It seems probable that the country traversed by the Mahanuddy to which the Bengal Military Board particularly allude, would also, if examined, prove to fall from the banks of that river, and to be susceptible of irrigation in the same way as the combined Kistna and Godavery Delta. This conformation may indeed be predicted of all country inundated by the overflow of rivers, the sediment of which is deposited in greatest quantity near their banks; raising the neighbouring ground and gradually forming a slope in reverse of that which first determined the course of the stream.



On both banks of the Kistna and on the west bank of the Godavery the meeting of these two slopes is occupied by the drainage of the great inundations, and has been made use of to serve as channels for irrigation also, but, as it is necessarily low in level relatively to the ground to be irrigated, this arrangement adopted by the natives probably to save immediate expense, and to secure the flow of water, is not recommended for imitation.

17.—Most of the works in the Madras Presidency are old native works, such as have been kept in repairs and in use, or such as have been restored or modified by the officers of the British Government. The positions adapted to the formation of tanks have for the most part been already occupied, and very few of the rivers or even mountain streams have been allowed to reach the sea without having been forced to contribute some of their water to channels and reservoirs. There are very few complete systems of works which owe their existence to our Government, although there are, on the other hand, but few works which have not undergone alteration, repairs and improvement since the countries came into British possession, and the attention of scientific officers was directed to them.

18.—In consequence, among a vast variety and number of works there are few or none that could be held up as models for close imitation while the irregularities in the slopes and widths of channels, the crookedness of their courses, said in some instances to have been determined by astrological considerations, generally turned to avoid difficulties by no means insuperable to our more efficient means, and always subjected to the caprice and the interests of petty proprietors unbalanced while

under the old unsettled Governments have prevented the obtaining of such useful data as might have been derived from observations made on works constructed more according to principles of art.

19.—The Bengal Military Board seem to have been much misinformed on the subject of ANNICUTS.

20.—The word "Annicut" is Tamil and means generally dam or weir. It is a pity that in English writing, English words, the signification of which is more *exactly* limited, should not have been used in preference. Our Engineers have with one exception (the Grand Annicut at the end of Seringham Island, which is a waste weir or diversoir) restricted the use of the term to a dam across a stream, and that of the word "Calingulah" to a work of similar form in the bank either of a supplying stream or of a tank. No such distinction is made by *those* natives, who have not been taught to make it by Europeans.

21.—The chief object of Annicuts is to raise the water of the streams they are built across, in order that a portion of it should be diverted into channels leading, as the case may be, directly to the fields or to tanks, in which the water is stored up to be used as required. Some Annicuts are like Calingulahs furnish with dam stones to sustain temporary banks of mud, &c. and to raise the water in the river beds during the dry season and the early and low freshes; such temporary embankments being washed away by the freshes, others are provided with sluices, or have low parts or gaps left in them seldom exceeding five feet each; within which limit, it is not difficult to provide means of closing, such as shutters, &c. By these, the sand is more or less prevented from accumulating to the height of the crown of the dam and parts of the beds of the rivers, generally inconsiderable however, are thus formed into pools extending towards their sources.

22.—These are in no instance looked upon, as the Bengal Military Board imagine, in the light of tanks. They may, for a trifling period at the very end of the dry season, answer the same purpose, but the irrrigation depends in all cases, either upon the continual flow of a small quantity of water during the early part of the hot season, or upon tanks generally far away from the river, and which are supplied by channels during the freshes.

23.—Almost all the rivers in the Carnatic, are little more than beds of dry sand during the hot season, and very little water can than be procured from them for the purposes of irrigation. During the monsoons they are more or less full, and it is then only, or at least chiefly, that a portion of their waters is diverted by means of Annicuts and channels into the adjoining country, to fertilize and moisten the rice and garden lands. During the periodical rains there is generally too much water, and in the hot months none, and the object of all the expedients and works of irrigation is to rectify these evils, by collecting and retaining in tanks or reservoirs a portion of the surplus water of the monsoons for the irrigation of the country during the dry season.

24.—When the slope of the country is gradual, it is evident that a dam across a river may, by raising the water in its bed, very much diminish the length of an irrigating channel to be led off it, and it might appear that Annicuts would on this account be found generally in the lower parts of the courses of rivers where the fall is gradual. But this is not the case, because the lower parts of rivers are generally wider, their beds sandy and unfavourable to such buildings, and their banks low. The obstruction of the bed in such localities would raise the surface of the water in freshes and render necessary the formation of banks to prevent the inundation of the

country through which the river passes: for, however advantageous such inundations are in the Deltas of the Ganges and Godavery, they are most carefully guarded against on the banks of the Cauvery and Tambrapoorny, where the crops are raised not by *inundation* but by a very artificial and (as far as the science of agriculture is concerned) a very perfect system of *irrigation.*

25.—Annicuts are most generally useful nearer to the sources of streams where they traverse rocky country. In such situations, rocky foundations can generally be obtained, and the work built securely; while, although the fall of country is great and channels do not need to be very long, yet without Annicuts, the difficulty arising from the nature of soil, in such parts generally stony, and which it would be necessary to excavate to a great depth, would be very often absolutely insuperable.

26.—A rocky bed though a great advantage, and always to be preferred in selecting a site for an Annicut as contributing to reduce the cost and increase the stability of the work is not however an indispensible requisite. Several Annicuts have recently been built with perfect success and at a moderate expense across rivers, the beds of which consist entirely of pure sand to a depth far beyond the foundations of these works. On such occasions, the chief point to be studied is the formation of a strong and substantial apron beneath the Annicut to break the overfall of the water, and prevent the foundations being undermined. The manner of doing this will be understood from an examination of the plans and Sections of the Coleroon Annicuts.

27.—Generally in the wide and flat beds of rivers near their mouths the scanty supply of water during the dry season is collected and turned into channels by means of the temporary embankments of grass, baskets, sticks and sand which have already been mentioned by the name *Corumboo ;* but there are two modern Annicuts in such situations, mention of which must not be neglected even in a notice so cursory as this is.

28.—These are the upper and lower Annicuts across the Coleroon, built at the suggestion and under the superintendence of Captain Arthur Cotton of the Madras Engineers. Both these works have superseded and rendered unnecessary the construction of extensive Corumboos; while unlike Corumboos, they resist the action of freshes and assist the irrigation in all states of the river. The upper Annicut is built were the (Agunda or whole) Cauvery divides into two branches, the Coleroon which seeks the sea by a straight course falling at the rate of about 2 feet per mile, the smaller but more useful branch (which retains the name of Cauvery) flowing on a more elevated bed, and, after having in the short distance of 40 miles gained no less than 15 feet on the level of the bed of the main branch, dividing and sub-dividing until its ramifications spread over the greater part of the Tanjore district, in irrigating which almost all its water is gradually exhausted. For many years previous to 1836, the Tanjore cultivation had pressed so closely upon the supply of water afforded by the Cauvery that in seasons falling at all below the average, extensive tracts of valuable land either remained uncultivated or were subject to the still greater evil of being cultivated in vain. The defect was chiefly attributed to the accumulation of sand in the upper part of the stream near its separation from the Coleroon, to remove which various expedients were devised and adopted with partial, but only temporary success and inadequate to the necessities of the case. At this conjuncture, viz. in 1836, Captain Cotton, then Civil Engineer of the division, devised the Annicut which is built across the Coleroon about 100 yards below the separation of the two rivers, and by raising the bed of the Coleroon about 6 feet has, without diminishing except in a trifling degree the capacity of its section for the passage of high freshes, rendered available for the supply of the Cauvery and of Tanjore all the water which even in

the driest season and when most wanted for irrigation, used to pass waste to the sea. The lower Annicut was built in the same year about 70 miles down the same river, and serves to turn the water that accumulates in the intervening part of the river bed from the drainage of cultivation, and the springs that ooze from the sand into the country on both sides, and irrigates extensive and fertile tracts of land in the Tanjore and south Arcot districts between the Annicut and the sea.

29.—These two works are very similar in form, consisting of walls of brick in chunam, the surface only being covered with cut-stone, the foundations of which rest on rows of brick wells sunk in the sand and filled with rubbish, and are protected by an apron of stone work, on the paved surface of which the water falls, and its tendency to undermine is in great measure broken and destroyed. Several sluices or vents of 3 to 6 feet by 3 to 6 feet have been left in the body of the work, for the purpose of allowing the water to flow through in high freshes, and carry sand with it, but the capacity of these is not sufficient to exercise a decided influence on the bed of the river, and it has in consequence, notwithstanding these contrivances, been generally much raised by deposits of earth and sand in front of the dams. Many of the details of these projects, and the principles on which they are built, will be found in the two reports printed at pages 63 and 131 of the professional papers of the Madras Engineers, and it is not necessary to repeat them here.

30.—Details of other works, and much of the information applied for in the fifth paragraph of the letter of the Bengal Military Board, may be gathered from the accompanying *(vide Appendix)* plans and reports selected from among the records in this department. These speak for themselves, but it may be important to remark that to ensure the stability of masonry works through, or over which water flows, too great care cannot be taken in regard to their foundations.

31.—In most of the accompanying drawings will be perceptible the anxiety with which the fall or rush of water has been, by those who designed the works, as far as possible, removed from the body of the works; but some of them will perhaps suggest a doubt whether the expense of labour and materials bestowed in adding external defences might not have been better applied in making the foundations of the work themselves wide and deep enough to have been secure without the appendages of apron below apron, retaining walls, &c. &c.

32.—The most perfect specimen of river and channel irrigation under this Presidency, is, that of the Delta formed by the Coleroon and Cauvery rivers in the provinces of Tanjore. A large portion of the waters of the two rivers, is consumed in irrigation, and the numerous channels with their ramifications spreading over the country, and throwing off smaller branches as they proceed to irrigate and fertilize the fields, bear a strong resemblance to the veins and arteries of the human body.

33.—The system existed in considerable perfection when the province came under the British rule, and is a proof of the attention bestowed on irrigation by the Native Princes, and of the possession by the inhabitants of much experience and practical knowledge of the principles and laws for managing and conducting running water,—all that has since been done, has been to improve and extend the same system by the application of European science, and to render more abundant and certain the sources of supply.

34.—A sketch of the rivers and channels is now under preparation, which, with a memoir on the subject by Major Cotton, will be forwarded for the purpose of being transmitted to the Bengal authorities, as soon as completed.

WORKS FOR IRRIGATION.

Extract from a Report by Lieutenant KEATINGE, *Assistant to Superintendent in Nimar, dated 17th March 1848, regarding certain works constructed for purposes of Irrigation in the vicinity of Mundlaisir.*

3rd.—As regards the map and its accompanying sections,* I have only to remark that the dotted lines in the Mundlaisir tank indicate the courses of the Choolie and Chupree nullahs, before the bunds were raised; and that in the weir sections, the shade of Indian ink is to represent the height of the sluices which pierce them. The dull green, represents the irrigation that has always been carried on; the bright, that which is consequent on the improvements detailed below.

4th.—Till the year 1845, the Choolie tank was only the size indicated in the inner line on the map, so that after heavy showers, it often overflowed into the nullah, the water running off unused to the Nerbudda.

5th.—In good years, the Mundlaisir cultivators raised an earthen bund, at A. in the map; and irrigated with the aid of wells, the part market as dull green. It appeared to Captain French that a bund of masonry could with great profit be erected at that place; and in August 1845 he commenced it. When however he found that Choolie held so little, he caused the old Choolie dam also to be repaired, leaving at the same time a sluice, to let the water off to the lowest level to which the people of the place ever drained it. It now takes very heavy and continued rain to flood Choolie tank.

6th.—In July 1846, during heavy rains, the water in the Choolie nullah, above the bund, rose to such a height that it overflowed its banks, and began cutting its way into the Chupree nullah. Captain French, accompanied by all the working population of Mundlaisir, proceeded to the spot, and for some time made vigorous exertions to stay its progress, by the erection of an earthen bund. But the water having once got its way, was not during that fresh to be restrained by any efforts of theirs; and on its subsidence, left a wide deep cut, joining the two streams. (See dotted lines, map.)

7th.—The bund at A. was thus isolated, and it became apparent, that unless this fresh channel was in some way stopped, not only would the new masonry bund stand useless, but the irrigation that had hitherto been carried on, would be rendered unfeasible.

8th.—After a careful examination, Captain French selected a spot, B., in the Chupree nullah; and there, in August 1846, raised a large solid earthen embankment. The two streams, thus dammed up, form the Mundlaisir tank.

9th.—C. D.—a portion of the road from Mundlaisir to Choolie and Mhow,—always bad and swampy, became absolutely impassable when the water rose in the Mundlaisir tank, and it was found that the usual passage of the Choolie nullah, just below weir No. 1, became so deep as to be impassable to laden cattle. Under these circumstances, Lieutenant Evans, then Bheel Agent, took some cross levels on the tank, and it was found, that by raising the masonry bund, at A., 3 feet (see section;) and making a straight raised road, C. D., the tank could be made to contain more than double its former measure of water. Weir No. 1, which then only consisted of the portion X, (section,) had a causeway of stones and rubbish, piled in the upper side, supported by a slight revetment, Y., over which the water flows during the

* *Vide* Appendix.

periodical floods, leaving an ankle-deep ford passable under all circumstances. These improvements were carried out during the rains of 1847.

10th.—I have not thought it necessary to mention separately the time each of the intervening weirs was constructed. They were built at different periods, when prisoners could be employed with advantage, and when other local circumstances made it convenient.

11th.—There remains now, I believe, but to show the manner of using these weirs. At the beginning of the rains, the sluice at Choolie being closed, and those of the intervening weirs open, the first freshes pass through them, clearing out the mud. All are then closed, and the rains soon fill them to overflowing. After the rains, when the calls of the irrigation canal begin to empty the Mundlaisir tank, a fresh supply is let off from Choolie; and should that fail, the weir sluices can also be opened. The tank is thus several times replenished.

Owing to the heavy rains that fell late this season, the latter supply has not been called into play, and these pools of water have been left for the use of cattle, and for general agricultural purposes.

It would perhaps be necessary to state that these works, so near the Agency head-quarters, have not been quite neglected as to appearance; some masonry drains having been built, hundreds of trees planted, and a pavilion raised on the bund (see section on the Choolie and Chupree nullahs) by a subscription amongst the natives of the town.

In concluding this account of the improvements near Mundlaisir, it would, I consider, be unfair not to mention in connection with them, the name of Deerij Bim, jemadar of the Nimar police corps. This indefatigable old man has worked at them from the beginning, not as a mere duty, but with all his heart and soul, making them the occupation of his life; and with him many new propositions originated.

IRRIGATION OF TURRAI LANDS.

Report by CAPTAIN W. JONES, *Engineer, on his first operations for improving irrigation within the Turrai lands of Zillah Bareilly, to* J. THORNTON, ESQ., *Secretary to Government, North Western Provinces, Agra, dated 1st August 1847.*

SIR,

I have the honor to forward the following account, of what may be most appropriately termed, the completion of the commencement of my operations, for the better management of the irrigation of the Turrai pergunnahs, of the district of Bareilly.

2.—To enable me to explain myself clearly, and without diffuseness, it will be necessary for me to refer to my report, dated the 27th April 1843, (*vide* page 105 of the "documents relating to the Rohilcund canals,") printed by order of Government. In that report, I endeavored to present a brief statement of the lamentable and increasing deterioration of the Turrai pergunnahs, selecting Roodurpoor, Gudderpoor, and Chowmilah. I proposed measures, the carrying out of which would in all probability tend to increase their cultivation, and diminish the so fatal malaria; and I recommended a general system of superintendence, to economize the water, and extend its benefits. Rough estimates were submitted for damming up the river Kitcha, on the borders of Chowmilah; for rendering available the Kylas in Kilpoorce; for draining an extensive swamp near Museet, in Gudderpoor; and for restoring the river Bhore to its natural and original channel, and rendering it available for irrigation.

3.—With the exception of damming up the Kylas, the waters of which river shrink to a very small volume, during the months of April and May, all these projects have been carried out, along with several others to be mentioned hereafter. Many square miles of morass have been drained; waters have been rendered available for irrigation, that were formerly wasted in pestiferous swamps; cultivation has considerably increased; and I begin to hope, that the promises I held out are not altogether visionary.

4.—In the early part of the year 1844, I entered the Turrai, with instructions from Government to commence, without delay, such projects as I thought most advisable to be undertaken at once. I was distinctly made to understand by his Honor the Lieutenant-Governor, North Western Provinces, that my operations were not set on foot with a view to any direct pecuniary profit to the Government; that the benefit, the health and the comfort of the people, were the great objects I had to bear in mind; that I was to act as their counsellor and friend in all cases of difficulty connected with irrigation; that I was to make pecuniary advances for the construction of canals or dams, on the most favorable terms for them consistent with security, whenever I thought it to their advantage; to settle their disputes on the spot, without forcing them to have recourse to distant Courts of Justice: and to study, to the best of my abilities, the improvement of their condition. Every assistance that I could reasonably expect, or wish for, was put at my disposal; and the natural difficulties of the country, added to an impoverished and unenergetic population, were the sole obstacles I had to contend with.

5.—The accompanying map* shews the pergunnahs of Gudderpoor, Roodurpoor, Kilpooree, Chowmilah and Ritcha. I have compiled it from the books of the

* Appendix.

Revenue Survey, and although I cannot boast of the correctness of my data, they are perhaps sufficiently accurate for a sketch of the scene of my operations. The two last-mentioned pergunnahs, being open and cultivated, are probably as well mapped as any other part of the district surveyed by Captain B. Brown. The incorrectness of the remaining part of the map is to me, however, more than problematical; for knowing the country as I do, recollecting my own feelings of forlornness and hopelessness, when I first found myself in a wilderness of waving grass, higher than my howdah, and knowing the extreme difficulty, even when on the spot, of procuring correct information regarding the course or name of the deep muddy nullahs which intersect the country in every direction, and render it next to impassable without a good guide, I can scarcely wonder that the assistant surveyors were somewhat daunted by the difficulties of their task, and supplied many of the hiatuses in their work from their imagination.

6.—The Bhaubur, or forest tract, I have not attempted to represent, as well on account of the absence of data wherewith to compile a correct map, as, because I do not attach any great importance to it, as far as irrigation is concerned. We generally find that the hill people are in possession of the country on each side of the rivers immediately at their debouchure from the mountains, and what little water escapes from their rude dams, is speedily absorbed in the broad shingly bed through which these rivers hold their course. The tracts thus irrigated are by no means large, as partly owing to bad management, and partly to the nature of the soil, one cubic foot of water only suffices to irrigate fifty acres of land. It is doubtless possible, by attention and superintendence, to economize the water; and to render the land more productive, by substituting tobacco or other valuable staples, in lieu of exclusive cerial grains. The lower part of the Turrai, however, offers so much more favorable a field for improvement, that I do not advocate, for the present, any interference with these little oasises.

7.—With the exception of these small patches, the country from the foot of the Hills, to from 8 to 12 miles below them, consists of large masses of forest, intermingled with occasional prairies of high grass. The rich and abundant vegetation, has led many to imagine this to be a most fruitful region; and not a few, even of those who have experienced the pleasures and privations of a forest life, have been misled, by the fair outside, to suppose that an agricultural *El Dorado* lies hidden beneath it, ready to pour forth its treasures on the first adventurer who should dare to seek them.

8.—Never was there a greater mistake. The soil of the forest consists of a thin superstratum of rich vegetable mould, on a subsoil of shingle: not a well or spring is to be found in it; all attempts to find water even at a depth of 300 feet have failed, and nature seems to have opposed an insuperable bar to the improvement of this part of the country; the timber with which it chiefly abounds, the Huldoo *(nauclea obtusifolia)*—fair to the eye, and beautiful in its proportions,—is utterly worthless to the carpenter or builder; and, save the Catechu that grows on the banks of the larger rivers, and the small Sissoo trees that are found in the islands that are formed in their broad and tortuous beds, there is scarcely a tree in the forest, that is worth the trouble of cutting.

9.—The Saul forests I except, of course; but in their case again most erroneous ideas appear to be prevalent, regarding their value and position. The Saul wood that grows in the plains becomes almost invariably rotten at the core, previous to arriving at maturity; and all the timber now brought* to Bencoulee or Pillibheet, (the two

* All that is cut in our Territory.

great timber marts of eastern Rohilcund,) is cut either immediately at the foot of the hills, or more generally on some small eminence. There are many strips of Saul forest extending for some miles into the plains, but I repeat, as timber, they are worthless; and nature seems thus to have warned us against the experiment (that I have heard proposed) of making the forest useful, by planting Saul wood in it, to ensure a future supply for our gun carriage depôt, as well as for general use.

10.—About the termination of the forest, we find springs arising to the surface of the ground, which increasing and uniting in their progress, form the numerous streams that intersect the Turrai. This part of the country is inhabited by tribe of men called Booksahs,* whose chief characteristics are, disinclination to labor; fondness for the flesh of game, particularly wild hogs; and a wonderful immunity from the effects of malaria. They take advantage of the facilities they command for irrigation, to grow the little grain required for their own consumption and for the payment of their assessment, which is generally little more than nominal (from five to twenty rupees per village,) and the quantity of water wasted and swamps formed, to enable them to do this, is almost incredible.

11.—Here we have the hot-bed of fever and malaria; it is next to certain death to any but a Booksah, to sleep in this part of the Turrai during several months of the year; and I am, and always have been of opinion, that the effect of the exhalations from these spots extends for several miles north and south, and that the removal of them would tend materially to diminish, not the common intermittent fever indigenous to all rice-growing countries, but that peculiar form of remittent, known as Turrai fever,—the most fatal type the disease can assume. I have previously, in my printed report before mentioned, brought to notice the deadly nature of this part of the Turrai, and I am still of opinion that the system of drainage originated by Mr. Elkington, might be applied here with great probability of success, and at a very moderate cost. The plan I propose would be, to open a trench a short distance above, where the springs are seen to ooze out from the ground, and to lead off the water thus collected, by small cuts into larger main water-courses, or even into the beds of existing rivers. It might be necessary to aid the ingress of water to the trench, by frequent borings along its bottom to the depth of a few feet. The drainage would then be complete, and when the experiment has been once tried, its great success will, if I am not mistaken, lead to its general adoption.

12.—Below this line of springs, we meet the Pergunnahs of the Turrai, belonging to the plains. Of these, Gudderpoor, Roodurpoor and Kilpooree, are held in farm by Sheoraj Sing, a descendant from the old Chund-dynasty Rajahs of Kumaon. His father, Gomaun Sing, dying while he was yet a minor, the property fell into the fostering hand of the Court of Wards, and during that period it prospered. Since he arrived at his majority and took the reins into his own hand, things have not got on nearly so well, and notwithstanding the kindness that he experienced at the hands of the late Mr. Conolly, as well as those of Mr. Pidcock, considerable deterioration has taken place in the estates; and so far from being in a condition to advance the capital required for the improvement of his property, several years of economy and good management are needed to free him from the grasp of the money-lenders, into whose hands he has fallen. This is much to be regretted. I have rarely, nay, never met a native gentleman of more amiable character or more polished manners, and I feel convinced that it is pecuniary embarrassment alone, that prevents him from co-operating with me, with more energy than he has hitherto shewn.

* Mr. Batten, in his few notes on the Rohilcund Turrai, calls them a fickle and unthrifty race.

13.—Another difficulty to contend within these Turrai Pergunnahs is that, owing to their insalubrity, it is extremely difficult to get respectable managers or karindas, as they are called, to reside there. The Pathans, probably owing to their animal diet, thrive well enough. The Rajah, however, has a feud of long-standing with them, and is thus deprived of their services. The delicate frame of the ghee-fed high caste Hindoo, is utterly unable to withstand the repeated attacks of fever and ague, and the unhappy ryots are thus left to the tender mercies of drunken extortionate Kaets. The revenue is collected by "Bhutty" as it is called, the produce of the fields being gathered up into heaps, and the Karinda taking one-fifth in his master's name. The great power of extortion in the karinda lies in his delaying to examine the heaped up grain, as exposure to wet causes it to germinate and destroys it. I myself saw in several villages at the end of last February, the heaps of rice cut in October, still unapportioned, and half ruined by the heavy rain that fell in February. A handsome douceur to the karinda would probably have ensured an earlier visit. I could but feel and express my regret at my inability to punish the offender.

14.—Pergunnah Chowmilah was a highly cultivated one, and prospered exceedingly during the time that Mr. Boulderson was Collector. The villages fell into the hands of men of capital, and he, Mr. Boulderson, annually superintended the construction of a dam across the river Kitcha, at Keromnee, some four miles above the work I have constructed, which afforded abundant irrigation to the rice and Bijwa crops.* The annual disruption of a lofty earthen dam however has a violent effect on the bed and banks of the river. Mr. Boulderson's dam became gradually so difficult to construct, that it was abandoned, and Mr. Clarke's attempts to re-build it, or to construct one some miles lower down near Chilora having entirely failed, the cultivation soon began to fall off, and the Pergunnah would have been long ere this entirely ruined, had not, as I before mentioned, the greater part of the villages fallen into the hands of men of substance, who were able to bear with their losses.

15.—Ritcha is a fruitful and well-cultivated Pergunnah. It is intersected however with such a labyrinth of deep and mostly unused water-courses, as to be next to impracticable for ordinary carriage, and the difficulty of the irrigation is by the same cause greatly increased. The principal dams in this Pergunnah are in the hands of a few powerful zemeendars. The abuses, consequent on confiding the interests of the many to the hands of so few, will be adverted to in a subsequent part of this report; at present I shall say no more than this, that litigation and disputes connected with irrigation are very prevalent, notwithstanding that redress to the aggrieved, in the shape of compensation for ruined crops is so tedious and expensive a process, as to be next to unprocurable to the poor and oppressed *minor* zemeendars.

16.—In the early part of the year 1844, I found myself, as before said, in the Turrai, with all my work before me. I immediately commenced a cut or canal from the river Bygool, close above the village of Roodurpoor, for the purpose of draining the extensive swamp alluded to in my printed report, page 112, paragraph 28. The accompanying plan and section, No. 2,† will show the nature of the work. The river Bygool was originally a small stream, as it now appears in the upper part of the plan, 30 feet broad with a maximum supply in April of 60 feet per second.‡

* Bijwa is a course kind of rice, which serves for home consumption, and leaves the more valuable grains available to turn into money.

† Appendix.

‡ At the beginning of April last, I found the river to contain 56 feet per second; but at that time some 15 feet from the Dandee, and between 10 and 15 from the Bhugeia, had been thrown into it by me.

About 26 years ago, the late Nawab of Rampoor dammed it up at the spot denoted in the drawing, "*Nawab's dam to be destroyed.*" The water was raised by this dam to a height of above 20 feet, and the advantage gained by it was, that the water being raised to the level of the country, the water-courses required to be only a few feet deep, and the work was consequently well adapted to the rude system of irrigation generally practised in this part of India.

17.—The disadvantages were, that, the waters thus pent up, were thrown back nearly to the town of Roodurpoor, that instead of a small and neatly defined river bed, an extensive lake and noisome swamp occupied a considerable extent of ground. The high reeds and swamp, sheltered an incredible number of wild pigs and an occasional tiger, in the very heart of the once flourishing town of Roodurpoor; and the malaria engendered, was so fatal, that the universal testimony of the inhabitants, dates the destruction of Roodurpoor, from the construction of the dam. The swamp and lake have been drained. I have constructed an earthen dam five feet high on the river, at the point marked A., at the upper extremity of the plan; and the blue line denotes the direction of an excavated canal 20 feet broad at bottom, with a slope of 25 inches a mile, which leads off the water of the Bhygool into the Kurra. By damming up the Jhirra, at B., I am still enabled to avail myself of the old water-courses, and the whole of the country between Roodurpoor and the destroyed dam is drained. The fall to be got over in the canal, in addition to the slope I have given it, is 14 feet. I have managed this by four artificial falls, two of four, and two of three feet, each.

18.—In addition to the drainage of the swamp and lake, this little work has greatly improved the communication between Bareilly and Kumaon. The road through Roodurpoor and Manpoor, forms one of the principal lines for the timber trade of the Turrai. From the foot of the Hills (Bumouree) to Roodurpoor, it was originally constructed, and is annually repaired, at the expense of the State; that part however between Roodurpoor and Manpoor, was in a most wretched condition; it crossed the Bhygool twice within a few miles, and was intersected by some such troublesome pieces of marshy soil, that it frequently took two days for a laden hackery to get over this short distance, and about eight per cent. additional cost of transport was added to all the timber brought down that road. A reference to the plan will show the alterations effected. The Bhygool has been entirely avoided; the canal is crossed by a substantial bridge; the earth excavated from the canal, has been formed into a good raised road; the distance has been shortened by one-fifth; and the present road may be now travelled, even by a loaded hackery, in two hours, in lieu of two days.

19.—The total cost of this work has been Rs. 7,633-4-8, of which Rs. 6,000 have been paid by the Nawab of Rampoor, for whose benefit principally it was constructed; Rs. 1,000 have been paid by the District Road Fund, and the balance, Rs. 633-4-8, I have for the present charged to a grant of Rs. 2,000, that was made to me by the Government to enable me to commence operations. I shall require some funds to maintain the annual repairs, but I trust that the Nawab of Rampoor will find it to his own interest to keep the work in good order, and will aid me accordingly. I shall endeavour on my next visit to Rampoor, to persuade His Highness the Nawab to allow me to construct for him a vertical saw mill, on one of the falls on this canal, to be worked with a turbine; in which case Roodurpoor might be made a very convenient depôt for the Bareilly timber merchants.

20.—The draining of a large swamp near the village of Musseet, in the Pergunnah of Gudderpoor, had been particularly recommended to my attention by the late Mr. Conolly, and having set the Roodurpoor work in train of progress, I went to the place. A careful examination of the ground showed me that the river Bhore had formerly been tributary to the Nahul, falling into it near the village of Mulpoora. Nundram, the enterprising manager of the district, many years ago, dammed up the river near Beriah, and brought the waters down, through Musseet, to irrigate the southern portion of Gudderpoor lying between the Dukka and Nahul rivers.

21.—The sudden change of slope, from the original bed of the river to Nundram's canal, caused a great deposit of silt during floods, and the bed of the canal being only 30 feet broad, whilst that of the river was 110 feet, it followed that after heavy rains, the water spread over the country, and that in the course of time a swamp was formed; which in 1843 was several square miles in extent, covered with high grass, infested with tigers, and wild pigs innumerable; the soil was treacherous and in many places impracticable for an elephant; whilst the malaria engendered in it, tended in no small degree to the depopulation of the Pergunnah. The simplest remedy appeared to be, to cut Nundram's dam, and to allow the Bhore to become, as it was before, tributary to the Nahul. The irrigation of the villages, thus deprived of water, I proposed to effect, by damming up the river Dhukka near Umurea. This plan has been carried out, the swamp is almost entirely drained, and the dam on the Dhukka is built. The only inconveniences attending this arrangement are, *Firstly*, that a new distribution of the waters of the Nahul (now increased by the Bhore) becomes necessary; and *Secondly*, that the Rajah of Casheepoor, or rather his karindahs, have not behaved very fairly (with regard to the Dhukka) to their old enemies the Puthans. Both these difficulties will be, I trust, overcome; the Rajah will doubtless listen to reason in due time, whilst with regard to the Bhore, I propose taking from the Nahul, some three miles above its junction with the Bhore, as much water as I have now thrown into it, and by this means affording irrigation to that part of Gudderpoor, between the Nahul and Saingnee, now very insufficiently irrigated. The money expended by me on these works, (the dam on the Dhukka and a cut to lead the Bhore into its original channel) has been Rs. 682-1-6, of which sum, Rs. 398, is in train of liquidation, and the balance, Rs. 281-1-6, has been for the present charged against the original advance of Rs. 2,000.

22.—A dam across the river Kitcha, intended for the irrigation principally of Chowmilah and Ritcha, had also been recommended to my attention by the late Mr. Conolly, as well as by Mr. Williams, the Collector; and with the assistance of Mr. Volk, a German gentleman of considerable acquirements, whom His Honor the Lieutenant-Governor had sent to me on trial, I soon procured surveys of the river and circumjacent ground, with sections and lines of levels, to enable me to devise some plan of encountering the difficulties opposed by this formidable stream. The river Kitcha debouches from the mountains at Bumowree by the Almorah road. It is the recipient of the floods from Naince Tal, Mulwa Tal and Bheem Tal; and forms one of the principal lines of drainage to the lower Himalaya, between the Kosilla on the west, and Deoba on the east, when the rains on the mountains have been sufficiently violent to cause the lakes to overflow considerably. Floods come down this river, I *know*, 14 feet, and it is *said* 17 feet deep; large trees are borne along with them: and experience has taught me, that any dam constructed of sufficient strength to withstand the torrent, would in a short time be rendered useless, by the river leaving it, following another course, and probably leaving the canal head high and dry.

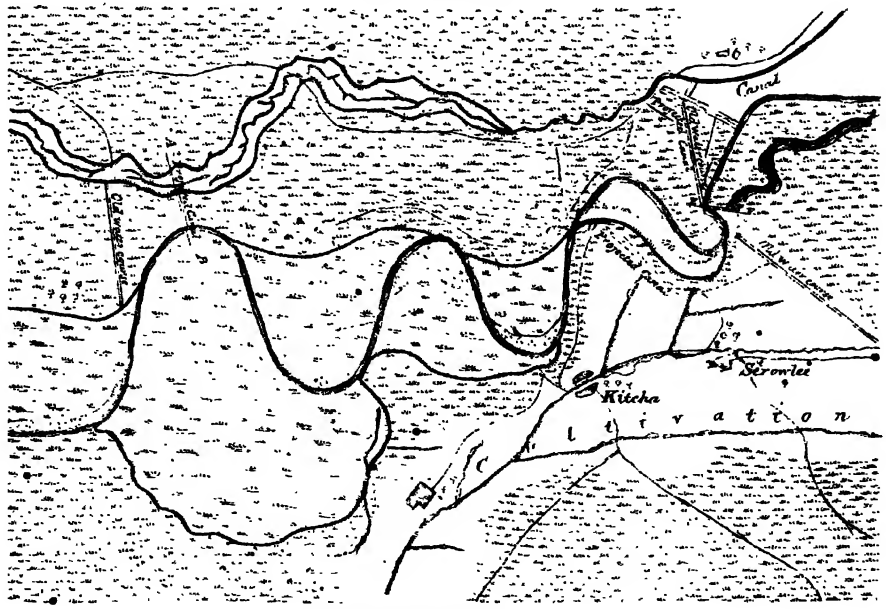
23.—During the dry months the volume of water at the site of my dam nearly opposite the village Kitcha, is about 120 feet per second: this would suffice to irrigate 30,000 beegahs of land under even tolerable management; and flowing as the river does through a rice-growing country, its agricultural prosperity entirely dependent on artificial irrigation, the zemeendars in the neighbourhood naturally enough took no small interest in the success of my project, and willingly entered into agreements to pay their portion of the expenses, rateably to the quantity of land irrigated. I soon found that my original plan of building a masonry dam with piers and gates at E, (*vide* plate No. 3,) would not answer; as, letting alone other considerations, the banks were so high, that unless I was prepared to expend some 25,000 rupees in earth-work, I should have been forced to carry the piers to a height of 12 feet. Mr. Volk then suggested building a dam of piles and timber at B, (plate No. 3,) cutting through the high bank, A, B, to the nullah at A, and clearing out the nullah from A to O, where an old water-course, the remnant of Mr. Clarke's work, would, when cleared out and enlarged, answer for the continuation of the cannal. It being necessary to deepen the bed of the nullah at A, an earthen dam was built across the river, immediately above it, and an escape opened to the river to prevent too much water lodging behind it. The entrance of the deep cutting at B, was protected by an earthen dam, with sluices underneath it, of timber and piles, it not having been found possible to get bricks ready in time to face it with masonry.

24.—The work answered its purpose very well, in so far that it afforded irrigation to 139 villages, and brought a great influx of ploughs and cultivators to many villages that had previously been rapidly deteriorating. I may cite as an example, the village Amdandah in Chowmilah, the first on the line of irrigation. It is assessed at 1,500 rupees, and has for many years been a heavy loss to the proprietor, a zemeendar possessing very large estates. The number of ploughs in it, in December 1845, were 40; by May 1846, the number of ploughs had increased to 110; and during the last year the village yielded a handsome surplus, after having paid its revenue. Many of the villages in Chowmilah were in a similar condition with Amdandah: indeed there were few which their owners would not have been glad to part with, previous to the canal being opened. That a considerable change in the value of land has taken place, may be supposed from the fact, that an agent of Nawab Malik Khan of Rampoor, was last cold season sent to Chowmilah with orders to purchase villages to the amount of a lac of rupees, but could find no one willing to sell.

25.—The heavy floods of July 1846, rising higher than they had been known to do for upwards of 30 years, caused sad havock among my works. The dam at A (plate 3) in the nullah, was overtopped and destroyed, as was the sluice at B, (plate 3,) and the river, rushing into the artificial channel or canal, filled up the bed with sand, 5 feet deep at its head, and diminishing gradually down to O, (plate 3,) where I had constructed another escape, to prevent the flood, in case of such an accident as occurred, from injuring the country. As soon as the season permitted me to re-visit my works, I proceeded to the scene of destruction, in company with Ensign Owen, 19th N. I., whom His Honor the Lieutenant-Governor, N. W. P., had been pleased to appoint as my assistant,—Mr. Volk having been removed to the Ganges Canal. I lost no time in clearing out the canal; re-building in a stronger form, the earthen dam in the nullah; enlarging the escape behind it towards the river; making a second escape round the dam; building a new sluice gate faced with masonry; and protecting the banks of the river, near the canal head, by weirs of very stout hurdles, bound together in a net work by piles 16 and 18 feet in the ground. Plates 5 and 6 are

No 3

SURVEY
of the
KITCHA RIVER
Near Serowlee.



Signed
W. Jones
Supt Embankments

Scale One Inch = [illegible]

[illegible]

descriptive of the works in their present condition. No. 5 is a general plan. E, F, is an earthen dam, across the river, 6 feet high, and rather lower at the centre than at the extremities. This is destroyed by the first flood that comes down from the mountains, and the river passing on undisturbed in its usual channel, I have less reason to fear any change of course. G, is the canal sluice gate, for a plan and section of which (*vide* plates 7 and 8); H, E, and M, are weirs of hurdles to prevent the stream on the back waters from cutting down the banks and turning the sluice gate. A, is the dam across the nullah, to keep the floods from entering the canal, and B, is the second escape to prevent the dam from being overtopped, in case the first C, D, should not suffice. Plates Nos. 7 and 8 are plan and section of the sluice gate. W, W, W, W, shew the position and foundations of the sluice erected by Mr. Volk. By unhooking the gates N, N, (*vide* section,) the canal becomes immediately closed, not to be opened again, until all danger from floods shall have ceased. My original estimate of 1845, was Rs. 15,670, and the total expenses up to the 1st May 1847 have amounted to Rs. 15,317-12-7.

26.—It now becomes a question, how the State shall be repaid this advance; how the annual repairs of the canal shall be executed; and how the irrigation shall be managed?

27.—The work *might* be made over to the zemeendars who receive water from it, on their paying the Rs. 15,317-12-7, together with a small cess, sufficient to cover the cost of annual repairs; or it *might* be made a Government work, and a rate be collected by me, from the irrigated lands, sufficient to pay 10 per cent. on the prime cost, and cover the amount of annual repairs, and the cost of collection. The volume of water flowing in the canal, 120 cubic feet of water, a second, would, according to Major Cautley's data, suffice for the irrigation of 42,000 beegahs of land. Supposing it, however, to happen that on an average number of years only one-half that quantity, or 21,000 beegahs, were watered; then, by charging three annas a pucka beegah, the sum claimed, whenever rent *is* charged in Rohilcund, I should clear close upon 4,000 Rs.; and allowing Rs. 1,500 to go to the interest account. I should have 2,500 rupees left for annual repairs; and the cost of collection.

28.—With regard to the collections on this, or any other canal in Rohilcund, some little knowledge of the subject, and a great deal of attention to it, have convinced me that a separate canal establishment is in every way undesirable, and that the duties of detail, connected with irrigation, should be managed by the tuhseelee officers. The tuhseeldar should receive a per-centage on the collections, equal in amount to a salary of between 50 and 100 Rs. a month, over and above his regular pay; and an addition to the ordinary tuhseelee establishment, to the extent of 500 rupees per annum, would fully cover the cost of realizing the collections under the tuhseeldar. Thus taking my hypothesis of a revenue of 4,000 rupees to be correct.

25 per cent=Rs. 1,000 cost of collection.
37½ ditto =Rs. 1,500 annual repairs.
37½ ditto =Rs. 1,500 interest on the original outlay—Rs. 15,000—*about.*

29.—This, be it remarked, is supposing the rate of irrigation or water rent to be so low as one anna per kutcha beegah. In fixing this supposititious rate, I have by no means followed my own inclination or opinion.* In the Saharunpoor district, the excess of produce of wheat on irrigated, over unirrigated land, is 554 lb per acre, the value of which, at 60 lb per rupee, is more than 9 rupees. I have no exact data in Rohilcund; but, allowig the proportion to be somewhat similar, a water rate of five annas per acre seems inordinately low. In rice land, the advantages of irrigation

* *Vide* Major Cautley:—The only statistical details on the subject that I possess.

are even more valuable. The average produce per imperial acre is about 1,875 ℔ whilst last year, owing to the very abundant rain, equivalent to as much water as is required, the produce was, on an average, in the Rohilcund Turrai, no less than 3,125 ℔ per acre. In some instances, where the soil was extraordinarily good, and water always available, the produce has been so high as 4,625 ℔ * per acre; the result of which ample crop was, that I myself met cattle laden with rice returning from the Pillibheet market, the owners *not* having sold their grain, because they could not find purchasers but at 120 ℔ for the rupee. Were I to be called upon to fix an arbitrary rate (for arbitrary it must be) I should say let it be 10 annas an acre; not that this is the actual value of the water, or nearly so: but by fixing that rate, I should be dealing tenderly with the zemeendars, and I should secure a sufficient return on the works I have at present on hand, to pay 10 per cent. on the Government outlay, to defray the cost of collections and annual repairs, to cover the amount of my own salary, and whatever surplus remained should be credited to the zemeendars, either in remissions, or in the building bridges and corn mills, or making other improvements, *connected with the canal*, for their sole benefit.

30.—To carry out this plan effectively there is one absolute requisite; namely, the most perfect understanding between the Collector and Magistrate, and the officer in charge of the canal. The former would naturally feel ill-disposed to allow an *imperium in imperio*, or to permit any one in whom he had not the most perfect confidence, to issue orders to his tuhseeldar; whilst the latter would find it no easy task to enforce obedience and attention, from an establishment, over which he could have but little direct authority, unless most strongly supported by the officer possessing that authority. In this respect, I am indeed fortunate. I believe that the Collector of Bareilly, Mr. Williams, feels thoroughly sure, that I would never issue an order to one of his subordinates, that I did not firmly believe would meet with his approval; and the support and assistance he has invariably given me, render my orders as effectual, as if they were given to men who looked to me alone for patronage or punishment.

31.—I should not omit to observe, that instead of the vexatious plan of enforcing fines for trespass on the canal banks, &c. &c., (although on such works as the Dooab Canal, I allow it to be absolutely necessary,) I would make each village responsible for the state of the canal banks within its own boundaries; cattle should be allowed a ghat to drink at, without charge, within each village boundary; and lastly, each village, not having a bridge within a very short distance, should be allowed a ghat for cattle and hackeries to cross.

32.—I would suggest for the better management of this work, that the provisions of Act VII. of 1845 be made applicable to it.

33.—In giving this rough outline of my proposed plan of conducting the Kitcha Canal, I should not omit to state, that I am desirous of introducing the same system generally on all canals in Rohilcund, constructed by, or the annual repairs of which are effected through, my agency. The river Dhora, containing nearly a similar volume of water with the Kitcha, but not like it affected seriously by floods from the mountains, flows less than a mile to the eastward of it. This river I dammed up last year with a common earthen dam, by the assistance, and at the expense of the Hoosainee Begum, a large landed proprietress. She has, through her agents, entreated me to take the work entirely under my own management, agreeing to advance the sum necessary for annual repairs, if I would engage to repay it out of

* The average produce of rice per acre in ordinary years, in Rohilcund out of the Turrai, may be estimated at 1 350 ℔; the highest 1,875 ℔.

the collections. A few miles east, the river Bhygool,* of about equal dimensions, has been dammed up by the same party, and in a similar manner with the Dhora, though with less assistance from me personally: this dam is now the subject of most fierce contentions. I have been entreated in an *urzee*, to take the matter entirely in my own hands, as the only way to put a stop to the litigation. West of the Kitcha again, the Paha river, considerably smaller than the other three I have mentioned, is the subject of constant disputes, and a large proportion of the zemeendars have entreated me to take it under my own management. Thus, within a space of less than 10 miles, four streams containing a volume of water nearly equal to the Dooab Canal, are now available for the irrigation of Chowmilah, Kitcha and the lower Pergunnahs; and the benefit of this abundant supply will be in a great measure frustrated, unless some regular system of distribution and general management be effected.

34.—The state of the irrigation, in the part of the country through which these water-courses are being led, is most lamentable. The country is intersected with a perfect labyrinth of old canals no longer made use of; or for the most part, they are generally dry:—a heavy shower of rain, however, fills them to the brim, and renders the country almost impassable for travellers, and entirely so for all wheeled carriages. No regulations or enactments having ever been passed, regarding the distribution of water for irrigation, or the relative position of the occupants of the banks of rivers and their neighbours, there exists a perpetual struggle between them; the latter endeavouring to obtain water on the easiest terms, and the former too frequently taking advantage of their position to exercise oppression, and gratify ill feelings. On examining the jummabundee, it will in no case be found that a village is assessed higher than others, on account of its having a dam across a river within its limits; and I come to the conclusion, therefore, that it was not intended, that a dam should become a source of revenue to the occupant. Generally, we find it simply stated that a dam shall be built at a certain spot, and that certain villages enumerated shall receive water from it, and they are assessed accordingly as *irrigated*. The right of villages thus assessed to receive water, appears to me to be equally if not better founded, than that of the occupant of the dam to hold control over the water, whether for good or bad ends. The right of the former is paid for annually, in the shape of the difference of assessment between irrigated and unirrigated lands; and the Government is surely bound to uphold and maintain it, whilst whatever right the latter may be conceived to possess, can only be by sufferance, or prescription.

35.—Under any circumstances, the occupant of a dam must naturally have considerable influence; and villages possessing this advantage are in consequence eagerly sought for by, and generally found in, the hand of man of wealth, who but too often exercise that influence, to the injury rather than the benefit of those around and dependent on them. By far the greater number of *urzees* that I receive at certain periods of the year are from the poorer zemeendars, complaining that the occupants of dams will not give them their water. However speedily I may issue my orders, I can scarcely prevent the complainant's crop from being seriously injured; and he fearing, not without reason, to sue in a civil court for damages from his powerful opponent, submits to any exaction, rather than expose himself to a repetition of the injury.

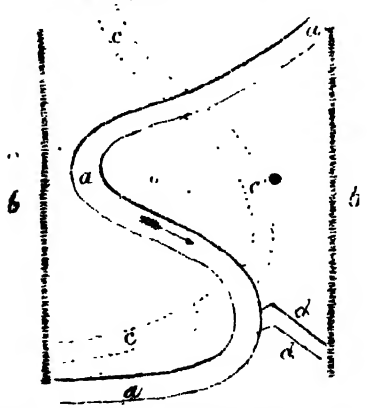
* Not to be confounded with the Bhygool in Roodurpoor.

36.—I do most sincerely hope that, sooner or later, some means will be taken to entirely overthrow the present system of irresponsible power, exercised by the occupants of dams; and that Government will put into the hands of its own officers, the control of the irrigation generally. Until that is done, permanent benefit can scarcely be expected. This is not the first occasion that I have taken, to bring forward the subject. It has been fully discussed during the last few months; and conflicting as have been the opinions elicited, there is I believe on one point but one voice: that the measure I propose, viz., taking the management of the irrigation into the hands of the Government, would be highly expedient.

37.—In mentioning the earthen dams across the rivers Dhora and Bhygool, I have been rather brief in my notice of them. The latter cost me but little trouble. No regulator having yet been applied to it, the canal is apt to burst its banks, and do some damage. The latter was first constructed last year. There was some deep digging on the water-course; above 12 feet at one part; and I took a regular set of levels along it. I am not practically acquainted with the violence of the floods along this river, and shall probably improve on the work considerably next year. In the mean time, it has answered very well for the past hot season, and the expences (about Rs. 2,000) have been entirely defrayed by the landed proprietress before-mentioned, on my agreeing to take the management of the work into my own hands, should the Government approve of it.

38.—Proceeding to the east, we find the river Deoha larger than the Kitcha, and of more importance. Flowing immediately under the town of Pillibheet, the great Rohilcund timber mart, it possesses sufficient volume, in the rains, to allow of large boats and rafts of timber passing down it, and forms the principal line of traffic for the Saul wood of the eastern part of the Turrai. Subject, like the Kitcha, to violent floods from the mountains, its channel is at times very broad and deep, whilst in the hot weather, it does not contain above 150 cubic feet of water per second. To throw this water into the rich adjacent Pergunnah of Beesulpoor, would be highly desirable; and at the request of Mr. Williams, I visited that part of the country last November; and having selected the spot offering apparently fewest obstacles, I surveyed and took the necessary lines of levels in the neighbourhood, and made a rough calculation, of what the work might probably be executed for. * The danger attending the construction of this canal is, that the channel of the river, *aa*, about 150 feet broad in the hot weather, is liable to vary in position between the high banks, *bb*, distant from each other nearly three quarters of a mile; these two banks forming the limits of the floods in the rains. Thus, for instance, the present channel, *aa*, might in time become altered to *cc*; in which case the head of my proposed canal, *dd*, would be sadly interfered with. I have during the last season limited myself to the construction of an experimental head, *dd*, at the cost of some Rs. 250; and should the floods have failed in doing it much injury, I shall probably take

* Rs. 20,000.



immediate measures, on commencement of the cold season, to construct a canal, from the point *d*, to a nullah distant from it a mile (similar very much to the work on the Kitcha). I shall then drain the nullah, and make use of it in a great measure as a main channel; only taking care, to have frequent escapes, to prevent the water rising above the height intended for it. Should this canal be carried out and *succeed*, which I see no reason to doubt at present, I shall be able to afford irrigation to 30,000 beegahs of land, at the moderate expense of Rs. 20,000. I say that I see no reason to doubt the success of the work, because the plan of restraining a river within a particular channel, by means of hurdles, clay, and piling, is by no means a novel idea, and has been carried out with success in France, by Monsieur Laval in Gascony.

Annales des ponts et chaussies Tuillet aout 1831.

39.—The average cost of a regularly built canal, on a slope of 18 inches per mile, in this country, is, I fancy, not less than Rs. 1,000 for every cubic foot of discharge. The Dooab Canal has certainly cost more. The little Nugeenah Canal has cost more, and I know of no canal that has cost less. The Kitcha irrigation works, (for *regular* canal it is not) have cost Rs. 15,000, instead of Rs. 1,20,000; and that Rs. 15,000, the zemeendars are prepared to liquidate within three years, should my proposal, to make the works Government property, not be attended to. True, they are not so pleasing to the eye, as more scientifically constructed works; they are more troublesome to manage; and they economize water less: but the end is obtained at a comparative trifling cost; the land is irrigated; remissions of revenue from want of rain are no longer to be dreaded; and should I meet with no unexpected obstacles, I shall have indeed reason to congratulate myself on having been appointed the means of conferring such a blessing on the country.

40.—It may appear, to those unacquainted with the subject, that I am inclined somewhat to overrate the magnitude of the obstacles opposed to me. The Muskurra river crossing the Dooab Canal certainly appears *less* formidable than either the Kitcha or the Deoha.* Every precaution was taken. Major Cautley, if I am rightly informed, had men posted, within hearing of each other, with muskets ready to give notice of the coming flood; and notwithstanding all his care, he could not prevent a solid masonry dam from being undermined by the force of the torrent;—tall trees are brought down from the mountains and tossed like feathers in its eddies: and the beachlike flatness of the country alone preserves it from frequent and terrible submersions. Piles, 14 inches in diameter, were driven by me, in 1845-46, from 12 to 16 feet deep into the bed of the Kitcha; several of these were torn up, and found on the river banks many miles down; and although, with the aid of gold and iron, there are but few natural obstacles that may not be overcome in engineering, I am convinced that the fewer the obstacles we offer to the torrents, the less frequent will be our disappointments. A bank of sand, 6 feet high, is destroyed by the first flood in June; the river then flows on its usual course, unimpeded: and by judiciously built weirs, I think sufficient influence over the direction of rivers may be maintained, to prevent any great deviation from the canal head.

41.—As my works progress, I trust to be able to introduce both corn and saw mills beneficially. I have hitherto only constructed one corn mill on the Nugeenah Canal. It pays 20 per cent. on its cost. The turbine has been recommended to my attention by His Honor the Lieutenant-Governor, North Western Provinces, and its great advantages will, I hope, be strikingly shown, should it be determined to put the forest at the foot of the hills under kham tuhseel management. The

Kitcha, Dhora and proposed Deoha Canals, are all favorably situated for an experiment of this sort, and I am only waiting for a fitting opportunity to institute one.

42.—The favorable terms offered to cultivators in the Turrai have led, with apparent reason, to a fear, lest any great improvement in its irrigation, might induce the ryuts in its vicinity, to resort to it in greater numbers than is desirable. I am not sanguine enough myself to suppose such an event probable. The principal benefits of my canals are to Chowmilah, Kitcha and Kaubur; pergunnahs highly assessed; and, with the exception of Chowmilah, thickly populated. In the case of Amdandah, before-mentioned, which increased in one season from 40 to 110 ploughs, it must be remembered, that in former years it was highly flourishing, and had ebbed to its low condition, on the discontinuance of Mr. Boulderson's dam on the Kitcha. It has now returned to its former state; many of its old inhabitants have probably returned to it; and as there is no reason to suppose the population now to be less than it was 10 years ago, the drain must be beneficial rather than hurtful, insomuch as things are returning to their former level.

43.—On examining a register of births and deaths in the Turrai, for the years 1844-45,—the only one I have,—I find that the former are to the latter as 1,031 to 1,820. A considerable influx of population therefore *must* take place at present, or it would be a desert in a few years; and if increased cultivation, drainage of swamps and regulating water-courses, tend to diminish malaria and mortality, immigration from the plains will on that account be less necessary than at present. What effect increased cultivation of, and attention to, the Turrai, (particularly the pergunnah of Guddurpoor,) may have on the adjoining jagheer of Rampoor, I am not prepared to state. There are circumstances connected with this subject however, that deserve consideration.

44.—Under the reign of Ahmud Ali Khan, late Nawab of Rampore, the effects of the tyranny of his minister, Dhoukul Sing, were very visible on the face of the country. The former died, and the latter was murdered in 1840. The present Nawab, Mohomud Syed Khan, passed his apprenticeship as a Deputy Collector in our service, when in indifferent circumstances, previous to his succession to the jagheer; and putting into practice the lessons he had learnt from Mr. Timins at Budaon, he (shortly after assuming his government) succeeded in considerably improving the condition of his subjects; at the same time greatly increasing his revenue.

45.—The jagheer of Rampore lies immediately south of Guddurpoor, Roodurpoor and Bazpoor.* The adjustment of the differences, between the Rajah of Kasheepore, (who holds in farm the two former pergunnahs and a share of the latter,) and the Nawab, with reference to their respective rights of property in the many streams that flow from the Rajah's estates, to those of the Nawab, is one of the most delicate and troublesome tasks that I have had to perform. The Rajah has by virtue of his position,—holding in farm from the British Government, a strip of land, 8 miles in breadth, above and adjoining the Rampore territories,—an abstract right to make use of the rivers passing through his property. Moreover, the terms of the present settlement with the Rajah, are those of a jumma *increasing* to a certain limit, and he is under a bond to greatly increase the cultivation by my assistance; and to enable him to do so he has been granted immediate remissions.

*A Pergunnah in Zillah Moradabad adjoining Guddurpoor on the west.

Any increase of cultivation, involves an increase of irrigation,—in other words, the construction of new dams; and the Nawab violently objects to any alteration in the irrigation of the Rajah's estate, it being now at as low an ebb as it well can be.

46.—There are but few public records extant on this subject, and those few are not very satisfactory. The river Nahul, flowing immediately under the village of Guddurpoor, has been for many years one of the chief sources of dispute and heart-burning. It is formed by the junction of the Nahul, the Barhut, the Ruknalla, and (since my operations near Musseet,) the Bhore. In a letter from the Governor General's Agent, Mr. Seton, dated 1804, the Nahul is made over to the Nawab, on the report of one Dureeah Khan. The Barhut was apportioned to Kasheepoor, in a roobakaree from Mr. Boulderson, 1835; and the Ruknalla and Bhore, have, from time immemorial, belonged to Kasheepoor. The Nawab claims all the four rivers thus united into one, which would, if agreed to, seriously injure the Rajah; who declares that the Nawab is only entitled to the Nahul proper, previous to the junction of the tributaries: an arrangement that would be no less injurious to the Nawab, than the other one to the Rajah. I temporarily settled this question last year, but must adopt some more permanent arrangement during the ensuing season. I am myself inclined to advocate a division of the waters, on the principle of share and share alike; that one-half of the waters of any stream, measured at a point two miles north of the frontier, be apportioned to each party: and that the same system be adopted to the southward, where the case is reversed, and the Rampore territories lie north of our's. This division should be made by me, in concert with an agent from Rampore, and submitted to the Governor General's Agent, Mr. Pidcock, who, should he approve of it, will finally order it so, and thus put a stop to all further litigation.

47.—The Nugeenah Canal in zillah Bijnour, though nominally in some measure under my control, owes the improvements that have lately taken place on it, more to the trouble Mr. Dick, the Collector, has taken, than to any thing that I have been able to do. By cleaning out the silt and sand that in a great measure prevented the flow of water, the discharge at the irrigation head has been greatly increased. The present year, though not a favorable one, shows a greater area of irrigation, than has ever occurred before, and the corn mill constructed on it near Nugeenah, has paid 20 per cent. on its cost. The collections on this work are effected (as I propose on the Kitcha and Dhora Canals) by the tuhseelee establishments, under the *peshkar*, who has yet received no reward for his labour. I think it advisable to give him, in future, a per-centage on all collections; partly as his just due, and partly to stimulate his zeal: and a proposition to this effect will be forwarded through the proper channel.

48.—My operations during the ensuing season, must be in some measure guided by the effect of the rains on my works. Up to the present date, August the 15th, no injury has occurred of importance; though it is but fair to confess, that the rains have been much less violent this year, than they were last. The floods of 1846 were 14 feet high in the bed of the Kitcha:—during the present year, the highest has been only 10 feet. In Guddurpoor, I trust to find the Musseet swamp, if not entirely vanished, at least not requiring any further outlay of money. The disputes between the Rajah of Kasheepoor and his Pathan mokuddums, I shall

endeavor to heal. By means of Mr. Batten's influence with the Booksahs, I shall endeavor to buy some of them out of their swamps, and turn the water down between the rivers Dhukka and Bhore. The *vexata questio* of the Nahul, will require to be decided likewise, and I shall be glad to find that the proposition made in paragraph 46, is thought worthy of adoption. I shall prepare a statement of the additional ploughs that have been thrown into this pergunnah during the last two years, and I think it will be found very satisfactory.

49.—In Roodurpoor, I have the repairs of the Roodurpoor Canal to execute. They will be troublesome, as the timber falls were seriously injured by a flood last season. I am in hope that the Nawab of Rampore will come forward with the funds to repair them, and enable me to build him a saw-mill. Mr. Owen, my assistant, will superintend this. The Kitcha Canal, being a new work, will of course require some repairs and additions. For a distance of 1,100 feet the digging is very deep, and the soil sandy. The rains have cut down the banks, I am informed, to some extent; in which case they must be covered with turf, and the sand that has been washed into the canal must be removed. The Dhora Canal having been hastily finished to allow of its serving for irrigation this season, will require considerable improvements and additions; and the water-course from the Bhygool, will require to be furnished with some safety valve or regulator, to prevent its flooding the lands of three small villages belonging to the Rajah of Kasheepoor. All this I can, with occasional visits of my own, confide to Mr. Owen. He gained considerable experience on the Kitcha last year, and I feel sure that he will exert himself.

50.—In pergunnahs Chowmilah and Kitcha, I have ample employment; and the distribution of the waters of the Paha, Kitcha, Dhora and Bhygool,—the laying out water-courses,—and introducing a regular system of irrigation, is a task, which I am scarcely sanguine enough to hope to be able to complete in one season. In pergunnah Beesulpoor, should I feel warranted in undertaking the Deoha Canal, I expect much assistance from Mr. Brown, the tuhseeldar; and a flying visit from me once a month, will be all that is required, until bricks are ready for a sluice-head. I shall, if possible, during the month of October, previous to entering the Turrai, visit the Nugeenah Canal; and in conjunction with Mr. Dick, the Collector of Bijnour, examine the river Ganghcea, and endeavor to introduce a series of regulating bridges and canals along its whole length, as far as the Moradabad boundary. I shall proceed with Mr. Batten, at such time as we may hereafter agree, to the Booksah villages in Guddurpoor and Roodurpoor, in the hopes of effecting some improvement in that quarter. Pergunnah Kilpooree, I have hitherto alluded to but slightly. The extent of the swamps in it, is almost incredible. I am unwilling to press the Rajah to put funds at my disposal to remedy this, knowing as I do his pecuniary embarrassments. I may perhaps submit hereafter an application for a grant of Rs. 2,000, to enable me to effect so desirable an undertaking.

51.—That further improvements are to be, and will be, brought about, I doubt not. I will not, however, indulge in speculations as to the future. A statistical account of the increase of ploughs, arise in the value of land, and a diminished bill of mortality, will be the best evidences of the success or failure of my measures;—to this detailed account of which, it remains but for me to add, the total expense that the State has been put to on their account.

* *Vide* Appendix.

APPENDIX A.

Statement of Advances made on account of works connected with the irrigation in Rohilcund, dated 23rd August 1847.

First.—2,000 Rs. originally advanced.	282 rupees have been expended in draining Musseet, and Rs. 633-4-8 on Roodurpoor. It is very desirable that these 2,000 Rs. be made a grant for the purpose of draining more completely the swamps in these pergunnahs.
Second.—4,000 Rs. for Pile Engines.	Rs. 2,914-2-6 have been actually expended, and Rs. 385-8-0 have been received back, as proceeds of works: there stands therefore a present debt of Rs. 2,528-10-6 against them.
Third.—15,650 Rs. advance for kutcha works.	Rs. 15,317-12-7 have been expended. The liquidation of this will be commenced at once, should my proposal, to make the Canal Government property, not be approved of.
Fourth.—20,000 Rs. for Deoha Canal.	Not disbursed.

REPORTS ON THE KHIRKEE AND CHUTTURPOOR BUNDS NEAR DEHLIE.

No. I.—*Report by* Mr. E. Battie, *in charge of Nujjuffgurh Jheel Works, dated 8th April 1848.*

1.—The remains of the numerous Bunds which are found in many parts of the Dehlie district, more particularly in the Southern Pergunnah, most convincingly attest the attention paid formerly to the subject of irrigation, and the great labor and expense incurred to secure it by means of these embankments.

2.—Some of these Bunds owe their origin to the enterprise of village communities; some to the munificence of individuals; and others to the Native Governments, particularly the Patan dynasties, who have left some immense works of this description.

3.—The Bunds are variously constructed; some being mere earthen embankments; others are massive structures of masonry, in the construction of which, neither labor nor expense has been spared.

4.—The remains of 27 Bunds have been found, and it is supposed that many more exist. Some of these Bunds are of great extent. Amongst the most remarkable is that known as the Khirkee Bund. It is a very extensive work and constructed of massive pucka masonry. This work could not have cost less (at a rough calculation) than Rs. 1,10,000: assuming a moderate rate (for work) of the present time.

5.—In the immediate vicinity of the present city of Dehlie, the remains of a most extensive work of this description, are still to be seen. It appears formerly to have connected the hills, near *Rohilla khan ke Suraee*, with the range that runs through the Military Cantonments, and ends near the river Jumna, about two miles north of the city. It is difficult, at this time, to ascertain the precise object for which this work was constructed, owing to the great changes caused by the formation of the Dehlie canal, and the consequent increase of gardens; to make room for which a great portion of this Bund has been destroyed.

6.—The southern portion of the district, being divided into numerous valleys by the ranges of low hills which intersect it, is admirably adapted for works of this description, of which the cultivators formerly appear to have fully availed themselves.

7.—The numerous ruins which are so profusely scattered over this part of this district, attest the presence, at some former period, of a much more numerous population than is at present to be found; and there can be little doubt, that instead of the present unproductive state, this part of the country was formerly well cultivated and fertile. It is with the hope of, in some measure, restoring this favorable state of things, that the re-establishment of some of these Bunds has been proposed.

8.—The Khirkee Bund (which is stated to have been constructed by the Emperor Feroze Togluck, about the year A. D. 1365,) was first repaired by Mr. C. Grant, Collector of Dehlie, in 1841, who closed up the lower range of openings with planks and kurries, but owing to the great quantity of water upheld in the rains of 1843, the planks gave way. The openings were then closed with pucka masonry, by order of Mr. J. Lawrence, and the whole faced with earth, and a small sluice constructed. This measure appears to have been effective, with regard to the stoppage of the old sluices. No escape, however, appears to have been provided, after a sufficient quantity of water had been collected above the Bund. The consequence was its giving

way at two places. The last of these failures was during the rains of 1846, since which the Bund has been repaired by Mr. A. A. Roberts, the Officiating Collector.

9.—Some idea may be formed of the force with which the water comes down, when it is stated, that it burst through the pucka portion of the Bund, consisting of a wall 10 feet in thickness, and faced and backed with earth about 20 feet thick on each side. It should, however, be mentioned that the wall, although intended to be pukca, is little better than so much rubble masonry: so badly are the stones cemented together. The soil is of such a light sandy nature, that great difficulty is experienced in keeping the Bund water-tight. Considerable quantity of water sometimes finds its way through the earthen embankments and pucka masonry, and springs up on the lower side of the Bund. During the month of August 1847, great apprehensions were entertained for the safety of the Bund, in consequence of a spring of this kind.

10.—Since the repair of the breach of 1846, the Bund has stood, and the nullah, above and in front of the sluices, has in consequence filled up to a depth of nearly four feet, by the earth brought down and deposited by the floods.

11.—One great fault exists in the whole of these Bunds, and which appears to have been the principal cause of the numerous failures, viz., no efficient *permanent* escape for surplus water having been provided after a sufficient quantity has been retained. The water therefore rises higher than is necessary, and a greater quantity is accumulated than the embankments can bear. The consequence is, the partial destruction of the Bund and the total loss of the water.

12.—Some permanent escape for surplus water should be provided, as it is useless to expect a native chowkeedar to exercise sufficient judgment, in opening sluices for this purpose, during heavy and continued falls of rain.

13.—To rectify this defect with regard to the Khirkee Bund, the upper range of sluices or arches should be re-opened. They are seven in number, and would give sufficient water-way. It would, however, be necessary to construct a pucka overfall or slope, in these arches, to adjust the surface of the upheld water to a point which would be ample for irrigation. Above this point the surplus water would have a free and permanent escape, as the upper portion of the arches would always remain open.

14.—The water could be reduced by means of the sluice, when required; or, instead of a pucka slope, movable planks might be fixed in the arches to the height required.

15.—Irrigation to lands below the Bund might be attained by means of the sluice.

16.—The force with which the water rushes through the old sluices of this Bund endangers the whole structure, as the bed of the nullah has been thus cut away immediately under the openings, and the foundations injured: indeed, cut away so much, that large masses of masonry, consisting of the whole lower facing of the sluices between the towers, have fallen into the bed of the nullah. The quantity of masonry, that has thus fallen, is very great, being nearly 20 feet in breadth at the centre of the sluices. The platform over the lower ranges of arches appears to have been originally 30 feet broad over the centre arch. It is now only about 10 feet; the remainder have fallen.

17.—It will, therefore, be necessary to secure the foundations of the Bund, at this point, by the construction of a floor and slope of rubble masonry, consisting of

the largest masses of stone procurable, to break the fall of the water from the upper openings, and to prevent any further cutting away of the bed of the nullah, or damage to the foundation of the Bund.

18.—It will also be necessary to point the whole of the face of the lower range of sluices, and fill up the interstices of the masonry, to prevent the falling water displacing any more of the stones.

19.—That portion of the Bund, situated between the sluices and the village of Khirkee, must be considerably strengthened with earth-work, both on the upper and lower sides.

20.—The Chutterpoor Bund is an earthen embankment of considerable extent being nearly 2 miles in length. It appears to have been originally constructed by the village communities in the neighbourhood. It would, if properly completed, irrigate upwards of 1850 beegahs of land above the Bund. Irrigation might also be given to the lands lying below the Bund, and to the right and left of the main nullah, by the construction of two pucka outlets, to the right and left of the sluice.

21.—The Bund would require a new sluice, (the present one being quite insufficient) the planks of which should be adjusted, so as to act as a permanent escape. The Bund will also require completing for 2,450 feet, and some additional earth-work to strengthen the places where it has formerly given way in 1845.

22.—The Bund was first repaired in 1843 by Mr. M. Gubbins and by Mr. J. Lawrencee in 1844. In 1845, this embankment gave way, and was afterwards repaired by Mr. A. A. Roberts, Officiating Collector, who also ordered the construction of the sluices. The Bund stood the rains of 1847; no great quantity of water was, however, collected.

No. II.—*Inspection Report* By Major P. T. Cautley, *(Bengal Artillery,) Superintendent General of Canals, dated 18th December* 1848.

Khirkee Bund,

(Three Miles East of Kootub Minar.)

1.—Mr. Battie, in his report dated Dehlie, 8th April 1848, has most fully and satisfactorily described this work. It is certainly one of very great interest, and from the style of architecture of the buildings attached, must appertain to a period, considerably before that of the Moghul conquest.

2.—The position of the Khirkee Bund, is eastward of the Kootub. The Bund itself has its left flank resting on a low line of rock, and its right terminates on what appears to have been a portion of an old fortified wall. The total length is about three miles. Its section is very considerable. On its whole length it is covered with the detritus of old walls and buildings; and the village of Khirkee, which occupies an ancient and very extensive mosque, is situated at a short distance from the main sluices of the dam, and on the top of the embankment. These main sluices are well described by Mr. Battie. They consist of seven openings, flanked by massive towers. These openings have, in former days, been regulated by shutters, as is attested by the sites of windlasses, grooves, and holes pierced for the chains or ropes with which the shutters were worked. The whole building is of that massive order, which characterizes all the buildings of the Puthan period in the neighbourhood of Dehlie.

The cost of this will be, in approximation,

No. 1 Earthwork, 10,00,000 Cubic Feet @ 2-8-0,	-- -- -- --	2,500 0 0
" 2 Weirs,	-- -- -- -- -- -- -- -- -- -- -- --	2,000 0 0
" 3 Irrigation drains,	-- -- -- -- -- -- -- -- -- -- --	200 0 0
	Total, Rupees --	4,700 0 0

I have requested Mr. Battie to draw up an estimate, in detail, in the usual form for the above work.

6.—It would be advisable annually to give a careful repair to the embankment, especially to that portion in front of which I have recommended the talus. It would also be beneficial, as opportunity offered, to extend the rear slopes, so that they may ultimately be 3 base to 1 perpendicular. I would not interfere with the young neem trees, which are growing in such abundance on the slopes between the mosque and the sluices. They would give a magazine of material for fascine making in the event of future leakage through the lower parts of the embankment, although in the projected additional slope, most of these trees would be buried.

7.—It appears to me that if the proposed works are carried out, very considerable benefit will be effected, and the objects of the dam itself practically brought into action. The advantage of the open weirs on each flank, is, that, immediately the surface of the reservoir rises above the maximum required height, the superfluous water will escape over a wide surface, without the aid or influence of any chowkeedar or establishment. From the irrigation heads, cuts would be made (*vide Sketch No. 3,*) on approved levels, so as to embrace and give a command over a quantity of cultivation. The tail of these cuts would fall into the main line of escape. The irrigation heads would require shutters, and the superintendence of a chowkeedar who would open them immediately, it became necessary, to lower the level of the reservoir, below the maximum height, as retained by the sill of the weirs.

8.—Should Mr. Battie be allowed to put this project into execution, I would suggest that he should be called upon to examine the line of valley below this Khirkee Bund, as the escape water from the Khirkee Bund might be retained again, to the great advantage of other tracts of arable land; it is probable that other ancient works exist south of Khirkee, which by a trifling repair, might be brought into use; at any rate, should the Khirkee Bund repair be authorized, to the extent recommended in this latter, I would recommend that Mr. Battie's attention be directed to converting the whole line of this valley into an irrigation tract, as far as means for collecting rain water may shew themselves.

9.—When I visited the Bund on the 9th current, the prospects of the rubbee crop, (wheat) on the upper, or that side of the Bund which had been inundated, were good; the appearance of the whole country was, as far as the eye could reach, green and beautiful. In the opposite direction, or on the lower side of the Bund, the prospect was quite reversed. With the exception of a few patches watered from wells, the whole country was dry and parched up. This would certainly not be the case under the project of irrigation drains above noted.

Chutturpoor Bund,

(Three Miles South of the Kootub Minar.)

This work has been fully described by Mr. Battie, in his report, dated 8th April 1848. It is situated about three miles due south of the Kootub, across the upper portion of the valley of the drainage of the Badshahpoor nullah. The Bund consists

of an earthen embankment merely; neither sluices nor revetment; with the exception of one masonry escape, 10 feet in width situated near the centre of the Bund, which is furnished with a shutter, windlass, &c. This work is roughly built of stone, and from its site being near the centre of the work, and therefore in the deepest part of the channel, there is a considerable retrogression of level upon its tail; so much retrogression, in fact, that unless immediate steps are taken for its protection, the work must inevitably sustain serious injury, during the next rains.

2.—During the late season, the quantity of rain which has fallen, has been very small; so small, in fact, that the sluice does not appear to have been used: but even under this disadvantage it is remarkable, to see the difference of the crops above and below the dam. Above, a sheet of green wheat and other rubbee crops, as far as the influence of the dam, and its inundated land had extended. Below, nothing but brown, barren, broken country. To those who doubt the advantages of canals and irrigation, I would strongly recommend a visit and walk along the line of one of these embankments. On one side, there are irrigation and verdure; on the other side, there are dryness and drought; and this comes so directly under the eye at once, that the impression is marvellously satisfactory.

3.—It strikes me that this Chutturpoor Bund is a work that might well be taken up by the Government, to be placed in perfect repair, and act as a pattern for others hereafter. The system that I would recommend is precisely that described for the Khirkee Bund. The principal being this, 1st, that the centre portion of the embankment being the highest, and consequently that most liable to accident, ought to remain intact and be strengthened and protected in every possible way; 2nd, that the escape of superfluous water, or water which rises above that point required for inundation, ought to pass over weirs, free and open, unimpeded by gates, and not dependent on establishment for regulation; that these weirs should be situated, one in the neighbourhood of each flank, or rather at points, as far distant from the centre, as may be considered less liable to lead to retrogression at the tail; that the width of the weirs ought to be great, so as to admit of a comparatively quiet passage of the water over them; 3rd, that, whereas the sills or wasteboards of the weirs are on a level with the *high-water mark*, or that level required for inundation, each flank of the embankment ought to have an irrigation drain, the sill of which is on a level with the *low-water mark*. These irrigation heads ought to be connected with Rajbuhas or water-courses, carried along on a proper level, and embracing all the country below the dam, in the fashion shewn in the Sketch No. 3.

4.—From the date, therefore, that it was considered necessary to reduce the water from its maximum height for inundation, these irrigation drains would be opened, and the water would be carried off by channels, so as to afford irrigation to the land below the embankment. If necessary, of course, these irrigation heads might be opened at an earlier period; but in common and average seasons, the plan would be that described above; the weirs retaining the water for the purpose of inundation, and the irrigation heads providing the means of reducing the water in the reservoir to its lowest required height, and at the same time distributing its benefits to the country below the Bund.

5—The present state of the Chutturpoor Bund is as follows:—

1*st*.—The Bund, or embankment, is perfect on its whole line, but it requires I imagine extension on its east flanks.

2*nd*.—The cross sections vary in their dimensions very considerably, at points where, in former years, fractures have taken place. The front or interior slopes have

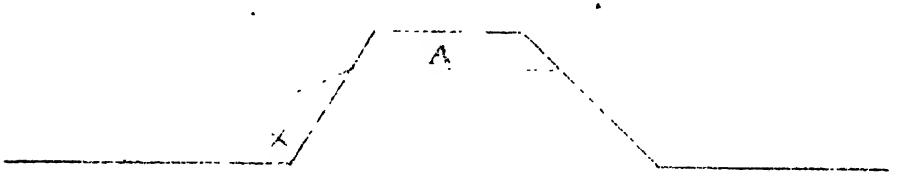
in those repairs been extended, but the general character of the section is a want of slope; portions of the Bund offer a nearly perpendicular wall to the front; and, generally speaking, the whole of the slopes require reforming.

3rd.—The height of the embankment is exceedingly irregular, and it has apparently been determined on no true line of level; the flanks terminate abruptly on the country, at a height of from 4 to 6 feet above the surface of the earth.

4th.—The masonry outlet is built in an awkward position; there is at present a perpendicular descent, at the tail, of about 7 feet, arising from retrogression of levels. To repair this a considerable outlay will be required. The plan of this sluice is to retain the water to its maximum height for inundation by a gate, and when the country requires relief from inundation, the gate being opened, the water runs off to *waste*, passing down the lowest channel of the valley.

6.—The proposed improvements are as follows: supposing that Sketch No. 4 represents the cross section of the valley with the embankment across it,—Mr. Battie would find out the maximum height to which the inundation reached, and at this point, he would build a bench-mark as at *A*. This bench-mark would be on a flank, and in front of the Bund. He would then carry out a line of levels cross the valley and construct another bench-mark at *A*., the two bench-marks being on one exact level. A line drawn from the top of one bench-mark to the top of the other, would give a zero, upon which operations would be carried. This zero line would also give the level of the sill or wasteboard of the weirs.

7.—The true top of the embankment would then be laid out, at a height of 36 inches above zero on the whole line of the work; and from my observations it strikes me that much earth would be procured for forming the front slopes of the Bund, by materials taken from the top, as represented below. The earth removed from *A*., in reducing the height of bank, to be thrown, at ×



8.—The general rule for the slopes ought to be thus—

Front or interior slopes 4 to 1 perpendicular:

Rear or exterior slopes 3 to 1 perpendicular:

and the whole of the slopes turfed, covered with grass, and kept clear from trees. At the foot of the exterior slope, however, I would recommend a belt of quick growing trees, to be used as material for fascines in cases of emergency; neem, bukoin, sonse, would do well for this purpose; and I would suggest an experiment of planting jao or tamarisk, which would be a most useful species of material if its growth were successful. The section of the Bund, on my project, would be as shown in Sketch No. 5, supposing the height to be 10 feet.

9.—The weirs would be exactly the same as those proposed for the Khirkee dam; the width of the passage for the water, being reduced to 40 feet, and the height of flank walls to 3 feet. The sluice now existing would be broken up, and the material would be used in the new works.

10.—The irrigation drains would be similar in every respect to those projected for the Khirkee dam.

11.—The cost of the masonry works will be, in approximation,

2 Weirs,	-- -- -- -- -- -- -- --	2,000	0 0
2 Irrigation drains,	-- -- -- -- -- --	200	0 0
	Total, Rupees	2,200	0 0

That of the earth-work cannot be determined without accurate survey, but the Government might be relieved from the expense of this by the use of convicts.

12.—I have requested Mr. Battie immediately that he can spare time, to encamp near the Chutturpoor Bund, build the bench-marks, described in the 7th paragraph of this letter, and take accurate levels, so as to give the points for the sills of masonry works, and the height of the embankment. When this is done, estimates shall be submitted in due form to the Government.

TIHARA CANAL.

Project for cutting a Canal from the left bank of the Sutlej, near Tihara, below Loodianah.

No. I.—Preliminary Note.

The following survey and project originated from a suggestion by Major Baker in his report to the Military Board, dated 24th September 1841, which was printed in a collection of papers entitled, Reports on Projected Canals in the Dehlie Territory, 1 vol. folio, Allahabad, 1842. In page 40 of that publication the subject is thus noticed:—

"An immense benefit might be conferred on a large tract of country, at a comparatively small cost, by opening a Canal from the head of the Sookha Nuddee, calculated to flow during the periodical rise of the river in the rainy season; and perhaps also by the smaller increase of water which takes place from the melting of the snow in May and June. No work would be required at the head, except the excavation of a wide channel, into which the water would flow when the river begins to rise. The channel would require to be extended for a few miles, through the higher land bounding the Khadir, and might then be connected with one or more of the natural hollows or lines of drainage; some of which, under the names of "Nyewal" and "Waharlee," were traced by Captain Brown, and are marked in the general Map, (Sheet No. 1); and two more were met with in my level from Bullowalla to Ferozpore; one of remarkable profile near the village of Boorra, and the other called the "Peeawalah Choya," (Sheet II. fig. 2). Supposing, for instance, that branch of the Nyewal to be adopted which passes Ubohur, we know that the difference of a level between that town and the head of the Sookha Nuddee is 120 feet, in about 90 miles, which would give a fall nearly equal to that of the Sutlej itself. A channel of 100 feet bottom width being provided, and average head water of 6 feet being assumed, (I saw flood marks 10 feet above the cold weather level of the Sutlej), a supply of water, amounting to upwards of 2,000 cubical feet per second, might be obtained during three or four months of each year.

"The effect of such a body of water being thrown over a dry country where rain is scanty and unfrequent, though not accurately estimable in money, will be easily conceived to be very considerable. By side-cuts, the water might be drawn off for the irrigation of khurreef crops, and the preparation of the soil for those of the rubbee. A great portion of the water would remain in tanks and hollows, for the use of men and cattle during the dry months; and even what may be absorbed in the soil would reinforce the under-ground springs, diminish the depth of water in the wells, and probably render sweet and wholesome many of those which now, over a large tract of country, are so impure and offensive, that none but natives of the soil can drink the water with impunity. Furthermore, there is perhaps ground to entertain a hope, that the measure suggested might even have a favorable effect on the quantity of rain. In the connexion which is always observed between the want of rain and barrenness of soil, the former is probably not altogether the cause of the latter; some mutual re-action probably takes place between them, and thus it may happen that a country of which the vegetation has been destroyed by a succession of drought, may for that reason be more liable to a recurrence of the evil, which in its turn would retard or prevent the renewal of fertility; and thus by a gradual process of deterioration, the country might become a waste, such as Bhutteeana now is. From the existence of the river beds traced by Captain Brown, unconnected as they are with any mountain range,

and shewing by the remains of towns along their course, that at no very distant period they were flowing streams, we may safely infer that these districts once enjoyed more abundant rain; and we may venture perhaps, to hope, that this blessing may in some degree be regained, by restoring fertility to a wide tract of country, the surface of which would also be cooled by the evaporation of a large body of water.

"The cost of such a work may be roughly estimated as follows:—

"For excavation of a channel 100 feet wide, through the high bank of the Sutlej, and clearing away obstructions, &c. &c. in the old beds of the rivers, about -- -- -- -- --	Rs. 40,000
"For the construction of two bridges; one a regulator on the Loodianah and Ferozpore road, and the other on the Military road from Ferozpore to Dehlie, or Kurnaul, at Rs. 5,000 each,	Rs. 10,000
amounting altogether to -- -- -- -- -- -- -- -- -- --	Rs. 50,000

"Of which sum, a considerable portion might be contributed by the Sikh chieftains, through whose lands the water must necessarily flow before reaching Bhuttecana.

"For the preparation of a more accurate estimate, and the determination of the best lines, a further examination of the ground, and a register of the height of the river for 12 months, would of course be requisite; but the above detail may suffice to enable the Military Board to estimate the value of the suggestion. On this subject, I will merely add, that in the Buhawulpoor territory, there are numerous canals, dry in the cold weather, but filled by the periodical rise of the Sutlej; and that Captain Brown, Revenue Surveyor, who is thoroughly acquainted with the province, has expressed a decided opinion in favor of 'the measure.'"

Political events which have since occurred on the N. W. Frontier, have diverted the attention of the Government from this subject, and no further steps have yet been taken towards maturing the project. The reports are peculiarly interesting, as throwing additional light on the physical features of that singular tract of country, which extends along the left bank of the Sutlej from the Himalaya range to Scinde.

No. II.—*Letter from* MAJOR W. E. BAKER, *Superintendent of Canals, to the address of the* SECRETARY *of the Military Board, Fort William, No. 122, dated Roorkee, the 27th May 1847.*

SIR,

I have the honor to forward, for submission to the Military Board, a report, accompanied by Map and Profiles, by Lieut. C. J. Hodgson, Engineers, on the Canal proposed to be taken from the Sutlej, between Loodianah and Ferozpore, for the irrigation of part of the Cis-Sutlej Sikh Territory, and of the Bhuttee States.

Forwards Report on Tihara Canal.

2.—Lieut. Hodgson has turned to good account the short period of time which intervened between his appointment and the commencement of the hot weather. His enquiries having been judiciously directed and prosecuted with vigor, have determined the true point at issue, and at the same time have brought out some interesting and important features in the topography of the country.

The object of Lieut. Hodgson's Survey attained.

3.—The plan suggested in my former Report on Sutlej irrigation, (dated 1841,) and approved by Government (conditionally on its being found capable of execution for the amount of my rough estimate, viz., 50,000 rupees) was, briefly, the excavation of a canal, from the Sutlej through a strip of high land bordering that river, to one of the natural hollows or depressions traversing the country from north-east to south-west.

Plan suggested in 1841.

4.—The grounds of this suggestion, were, the existence of certain dry channels, in the interior of the country, and the ascertained fact, that the ultimate difference of level, bore such a proportion to the distance, as to admit of a sufficient slope being given to the canal bottom.

Grounds of suggestion.

5.—The success of this measure would depend upon the direction of the natural hollows, and the levels of the country lying between them and the Sutlej. To these points Lieut. Hodgson's attention was chiefly directed.

Conditions of success.

6.—The result of the examination is unfavorable to the project. The directions of the natural channels are suitable enough, but the excavation required to connect them with the Sutlej could not be effected for less than four lakhs of rupees, or 8 times the amount to which Government has limited the expenditure for this object.

Result unfavorable.

7.—The chief obstacle appears to be the continuation, in land, of the high bank which borders the Sutlej from Roopur to Loodianah, and was supposed to cease at Bhoondri, (otherwise called Bhoondelee). This bank has been traced by Lieut. Hodgson, and is found to be continuous; passing by Moodkee, Mokutsir, &c., and joining the high bank or "Dunda" at Nowkheira, surveyed by Captain W. Brown, 1840, and forming the boundary of the Bhuttee and Bhawulpoor States, west of Ubohur. There is every reason to believe that the foot of this bank was once washed by the Sutlej, though now more than 20 miles distant from that river.

Nature of the chief obstacle.

8.—Referring the Military Board to the accompanying report, for further particulars regarding the features of the country examined by Lieut. Hodgson, I now proceed to point out the line, and to estimate roughly (from Lieutenant Hodgson's measurements) the cost of a canal capable of feeding the Nyewal and the Furreedkote and Nowkheira nullahs, and of irrigating the districts of Ubohur, Kotekapoora and Furreedkote, though not attainable at the cost originally contemplated, it still remains for Government to decide whether the object be worth the additional outlay now found to be necessary.

Object still attainable, but at greater cost.

9.—The head of the canal would be established under Bhoondri, at a point on the Sutlej where the flood level is 21 feet above the bottom of the nullah at Chogana, at a distance of about 20 miles. Deducting 6 feet for the depth of water, we have a clear fall of 15 feet, or about 10 inches per mile. The excavation on this line would be 11 feet deep, which, with a bottom-breadth of 100 feet, and a length of 20 miles, would give cubic feet 128,937,600.

Situation of canal head and fall to Chogana. *See Sketch Map.*

10.—From Chogana a portion of the water might be allowed to flow towards Furreedkote, Kotekapoora, Mokutsir, &c.; and the remainder, for the irrigation of Ubohur, &c., might be conveyed by a canal to Bugta on the Nyewal, a distance of 24 miles, following the course of the Chogana nullah to Pulwana. The fall in this distance would be 26 feet, or 13

Mokutsir and Ubohur branches.

inches per mile. From Pulwana to Bugta, 20 miles, average digging 8 feet, bottom-breadth 60 feet, would give excavation, cubic feet 57,446,400.

11.—Total amount of excavation cubic feet

Abstract cost.

186,384,000, at 2 Rs. per 1,000 cubic feet, --	Rs.	3,72,768
Add for 3 bridges, -- -- -- -- -- -- --	Rs.	15,000
and clearing out obstructions in old nullahs,	Rs.	12,232
Total, Co.'s Rs.		4,00,000

No data for calculating returns.

12.—The preceding paragraph contains I believe a fair calculation of the cost of the work, but I have no data for estimating the probable returns. These might perhaps be ascertained from the Revenue Officers.

Disposal of Lieut. Hodgson's services.

13.—Should it be considered expedient to expend four lakhs of rupees on this undertaking, Lieut. Hodgson will submit regular estimate for the work, as soon as possible after the rainy season. But if, on the other hand, the cost of the project be deemed conclusive against it, I would recommend that Lieut. Hodgson's services be transferred to the Ganges Canal.

No. III.—*Letter from Lieutenant C. J. Hodgson, Executive Engineer, Tihara Canal, dated Loodianah, 1st May 1847; addressed to the Superintendent of Canals.*

SIR,

Recapitulation of depressions mentioned in former letters.

In my letters Nos. 2, 3, 4, and 5, I had the honor to inform you, that I had in levelling from Tihara in a S. W. direction, fallen in with a depression at Chogana, about 11 miles distant from my starting point, which I had again crossed near Moga, and again, as I imagined, in the neighbourhood of Moodkee; and that I had ascertained the existence of a "Dunda," or old river bank, running through the country from Furreedkote to Naokheira: further, that I had traced the course of the westernmost Nyewal, from the neighbourhood of Mullote on the confines of Bhutteeana, to a village named Lapo on the Ferozepore and Kurnaul road.

Forwarding Plan and Profiles.

2.—I have now the honor to forward a general plan* showing the courses of these nullahs and banks, with profiles showing the relative levels of the Nyewal, and the Chogana and Furreedkote nullah, with the valley below the latter town.

Statement of nature of work since my last communication.

3.—Since my former communications, I have ascertained that the Chogana and Moodkee depressions have no connection with each other, and have traced them both throughout their course; have examined the "Dunda" immediately above and below Furreedkote; and have also followed Nyewal to its commencement as a distinct nullah, concluding by carrying up my level to the fort of Loodianah as a fixed point.

Origin and nature of the Nyewal and Chogana nullahs.

4.—The nullah first met with by me at Chogana, and the Nyewal, may be said to have their commencement within nine miles of each other; the one at Shekhopoora, and the other at Urkara; where they with another smaller depression, which afterwards joins the Shekhopoora and Chogana one, form the outlets by which the drainage of the

* *Vide* Appendix.

higher country to the eastward (over which the water flows during the rainy season in wide uncertain channels is carried off.

General description of the Chogana nullah from Shekhopoora to Demoroo, throughout its course.

5.—The depression from Shekhopoora to Chogana, is, as far as Jettowal, of great width, having several villages built in the centre of its channel, and is generally from 5 to 6 feet below the surrounding country. But below that village it is more contracted, the banks being generally about 6 to 700 feet in length without increasing in depth; from thence it continues, with a winding course, but distinct profile (except for a short distance from Chundun to Chotiya) to near Demoroo, where it joins what would appear to have formerly been a river bed, which may be traced from thence to near Furreedkote.

General description of the nature of old river bed between Demoroo and Furreedkote with the continuation of its left bank to the northward as far as Sulleena.

6.—This river bed, I first fell in with while crossing the country from Lopo to Furreedkote, and I then examined it throughout its length; but I have not surveyed it, and consequently am unable to lay it down with any accuracy. It is a wide and deep channel, averaging from half to one mile in breadth, with a continuous steep bank to the south, till within a short distance of Furreedkote, where it gradually loses its distinct character, and within the last mile becomes no longer distinguishable. The bed of it throughout is very uneven, intersected with ridges, and filled with enclosures, so that without a considerable amount of clearance and excavation it would form a very wasteful channel. At present, it is represented that water never flows along it, and indeed, towards the end, the bed evidently rises. The bank to the N. only commences at Nuthoowala opposite the junction of the nullah, while the S. and E. bank continues towards the north, and is in all probability a continuation of a bank of the same nature which I met with in my first line of levels from Moga to Moodkee near Sosun, and which I have since traced as far north as Sulleena, where I learned from the inhabitants that it commences near Esan Khan-ke-kote; but, as it did not appear to me to be likely to be of any use to the purpose of the present enquiry, I did not follow it any further.

Rise and course of the depression from Sosun by Moodkee to the Dunda.

7.—Below this bank, at Sosun, the nullah I had formerly crossed near Moodkee, takes its rise and runs, as shewn in the plan* to the Dunda, which it joins between Moodkee and Jundiala.

Account of the Dunda, or old bank of river from Moodkee to Naokheira.

8.—The earlier course of this Dunda I could not learn from enquiry of the natives; but the village of Moodkee is situated on the edge of it, (though it is here rendered indistinct by accumulations of sand,) and from thence it is to be traced very clearly by Jundiala, Misreewala, Pukka, to Furreedkote; from whence it continues, as drawn in the plan, to Mokutsir and onwards to Naokheira. For a few miles, a bank runs (so to say) parallel to the Dunda; thus forming a valley varying in width from ¼ mile to a mile, and even to considerably more than that in parts.

Non-existence of any depression at the foot of the Dunda (by which water finds a channel) above Wuttoo.

9.—In my letter No. 3, I informed you that I had been able to trace, at the foot of the slope of the Dunda, a continuous small basin by which the rain water finds a passage; but upon further examination I find that even this has no existence above Wuttoo, (the village at which I rejoined the Dunda in my first line of level,) but that the Dunda itself follows a very winding course, while the mouths of the bays thus formed are partially filled up with sand ridges, and above

* *Vide* Appendix.

the latter town, though its course is regular, yet there is no appearance of any channel at its foot, while the fall is from Furreedkote; the lowest part appearing to be about Pukka, at which place are traces of a flow of water to the westward. Below Wuttoo, the Dunda is unbroken as far as Naokheira.

10.—To consider, then, the facilities offered by these features for carrying water into the Bhuttee country from the Sutlej at Tihara:—

Consideration of facilities offered by these features to the formation of the Canal.

11.—The flood level of the Sutlej at Tihara to which the water rises, and generally maintains itself during the rains, may be taken (as far as I could learn) upon an average to be eight feet above the cold weather level; so that, allowing a head of 6 feet depth of water for a canal, the bottom level would be two feet above that of low water.

Levels of high and low water opposite Tihara.

12.—The nullah at Chogana is 2½ feet below the low water level at my starting point, (which was about 2½ miles below the head of the Sookha Nuddee,) or ½ foot below the bottom level of the canal at that point. At Moga the fall is 12 feet, while the distance from Tihara is 16 miles, and a fall of one foot per mile is not gained till below Singunwala, a distance of about 22 miles. The nullah from thence has a clear channel, about 5 feet in depth, with long sloping banks 6 to 700 feet in length generally, with the exception of the space between Chundun and Chotiya, where the waters flow over a wide flat; but beyond Demoroo, but little advantage appears to be offered by the river bed and the Dunda as a channel must be formed for the whole distance to the point from which it might be considered most advisable to commence a communicating cut to the Nyewal, which would have to be 25 or 26 miles in length, and excavated to a general depth of 15 feet, as shewn by Capt. Baker's level from Ubohur to Kattee.

Statement of levels of points in the Chogana nullah, with lengths necessary for communicating cuts from the river and into the Nyewal near Ubohur.

13.—The Nyewal nullah, having been traced by Captain Brown in his survey of the Bhuttee territory, as high as Danawalla in the neighbourhood of Mullote; I commenced my survey of it at that place, from whence I followed its course throughout to its rise.

Point of commencement of survey of the Nyewal.

14.—My starting point was at the Sirsa and Ferozpore road, where it crosses the depression, which has at this point an ill-defined profile. Immediately above the village of Danawalla, however, the depression assumes a more distinct character, which it preserves as far as Bhai-ke-kote, though the banks, which are here about 18 feet high, with a steep slope, diverge from each other to a mile or more distance, till near Tehree, where they suddenly approach to within 600 feet; beyond which the depth of the depression decreases to 6 or 7 feet, with a width of 14 or 1,500 feet. Above Bhai-ke-kote, the high banks separate widely; that to the north-west running by Sahebchund and Pulayun to Uboloo, while the S. E. bank is again found at Memah. Between them however are several distinct channels, two of which branch off from each other below Uboloo; one running round by Sahebchund, and the other by Bisseeana; and I think it probable that a channel also joins from the eastward running under the high bank by Memah. Above Uboloo, the bank to the N. W. continues no longer so high, but the depression is clear and well defined, bounded by long sloping banks not less than 5 to 6 feet high, as far as Mullah. Between Mullah and Bugtah I could not find any continuous channel, though they are partial ones running in two or three

Description of the Nyewal throughout its course.

directions. Bugtah is built in the middle of the channel, by which means the waters are thrown over a wide space, and Gooroosir and Pakrawadee are so also. From this latter village to Puttoo is a clear deep channel; but above Puttoo, the waters at present flow over a flat of great width, cutting small channels and pools in several directions. Near Lopo it is again confined between sloping banks 3½ to 4 feet deep, and 500 to 600 feet long each, which is its general nature from its commencement at Urkara. Here are collected the waters flowing from the eastward; and from the accounts I received, it appears that this depression is not sufficient to carry off the water brought down during high floods, which consequently inundate the country to a great extent, while during the whole of the rainy season a stream, breast-deep, ordinarily flows as far as Lopo. After spreading over a wide expanse below this, the water, as plainly shewn by the traces left, flows with considerable force as far as Pukrawadee, from whence as far as Mullah, the country is said to be inundated generally during the rains. Below this, the stream is dependent upon the nature of the season *in these parts*, being in good seasons not less than waist-deep during floods, and ordinarily throughout the rains continuing about ankle-deep, beyond Bhai-ke-kote. However, the inhabitants altogether reject the idea, that water ever flows along the depression, and at Mullote it is known as "the Jheel."

Nature of stream of water in it during the rainy season.

15.—The distance of Urkara from the river is not more than about 15 miles, but the bed of the nullah is not less than 25 feet above the river at the nearest point; and the relative levels of the river and nullah are such, that water can in no part be brought into the latter, direct from the river, with a cutting of less than fifty miles in length.

General level of the Nyewal with reference to the river.

16.—Nor do the Chogana and Demoroo nullahs offer much assistance: as the nearest point at which a channel can communicate from Demoroo will be at or near Sahebchund, a distance of not less than 28 miles; while I have above stated that the length of cut to admit water into this nullah cannot be less than 22 miles.

Lengths of cuts required to bring water by the Chogana and Demoroo nullahs into the Nyewal at Sahebchund.

17.—This appeared to me to be so little favorable to the project, that I did not think it advisable to delay for the purpose of obtaining the section of the country between these two points, more especially as I had not at that time followed the Nyewal, sufficiently far, to have ascertained the impracticability of introducing water directly into it from a higher part of the river.

The section of country between Demoroo and Sahebchund not taken.

18.—That these depressions which I have been able to lay down, are the only features of the nature in this part of the country, would appear to be but little doubtful; as below Furreedkote no nullah joins the Dundah. No feature of the sort was met with by you in levelling from Bullawala to Kattee; while my level was run almost entirely along the north-west bank of the Nyewal, and I found no nullah joining it; and, lastly, any such depression, should it exist, must take its rise south of the road between Ferozpore and Busseean, (in a country having a fall of not more than two feet to a mile,) as that road crosses no nullah: and, between two depressions I have surveyed, there is another smaller one, which is traceable to Lungiana, were it unites with that from Chogana.

Reasons for supposing that no nullahs exist between the two traced.

Course of levels above Urkara, with the closing point.

19.—Above Urkara, finding only a wide plain, over which the water sweep from the eastward, I ran a level across to Shekhopoora, and from thence followed the course by which the rain-water flows, as far as Munowr, from whence I brought it up to, and closed upon, the crest of the glacis of the fort of Loodianah, as a good fixed point, at which to commence or close any future survey; while it would be impossible for me to find, with any exactness, any point in your former surveys.

That copies of original plottings can be furnished.

20—Should you require them, I can forward to you either copies of, or the original plottings and sections, as I have laid them down in the field, on a large scale.

CANAL IRRIGATION OF VALLEYS.

Notes on the System of Irrigation prevailing in the upper valleys of the Kangra District; by G. C. BARNES, Esq., C. S., *Deputy Commissioner, Kote Kangra, Trans-Sutlej States.*

[*The chief object in publishing this paper is to show, how the preservation of the Canals, and the distribution of the water can be provided for by the people themselves, in a district, where artificial irrigation has long prevailed.*]

Introductory remarks.

The district of Kote Kangra is divided from the hill-principality of Chumba by a chain of mountains rising to an elevation of 14,000 or 15,000 feet above the level of the sea. On the Chumba side this range is the first and lowest of a series which stretches into the depths of Tartary and Thibet. On the southern, or Kangra side, the base of these hills extend in long and gentle slopes towards the river Beas, forming a noble valley, highly cultivated, and thickly peopled, known by the local appellations of talooquas Palum, Puthcear, Kangra, and Rihloo.

The tops of this chain are covered with snow for nine months of the year; and snow exists in the clefts and hollows all the year round. A number of hill streams take their rise in these mountains; and the waters, on their course to the Beas, are arrested by the people, and conducted by means of canals to the cultivated surface of the valley.

The extent of this irrigated tract may be roughly estimated at twenty-six miles long by twelve miles broad: and notwithstanding that much land is still lying waste, and many villages are alienated in jageer, the revenue paid to Government does not fall short of 2,25,000 rupees.

Canal heads.

The canal heads are at all points of the stream. Those destined to irrigate the upper portions of the valley, lie deep in the interior of the hills; and the canal courses are brought along the hill side at a great outlay of expense and trouble. The lower cuts are much more easily constructed; and generally a distance of a few hundred yards suffices to convey their waters to the cultivated level.

Embankments.

The water is diverted from the main stream by means of the simplest embankments made usually of the stones in the bed of the river, cemented together with a few green sticks, and (where allowed by custom,) with clay. These embankments seldom extend quite across the stream, but are placed at favorable turns, where the excavation of a new channel, assisted by a partial barrier of stones, is sufficient to turn off the quantity of water required.

On each of these rivers there are at least fifteen to twenty independent canals leading to various villages to the right and left of the stream. Between one embankment and the next, the supply is renovated by plentiful springs in the bed of the river; and thus an abundance of water is furnished, not only to the lowest canal, but a goodly stream is allowed to run to waste in the main channel.

Most of these canals have been constructed by the people themselves at their own expense. A few again are the work of individuals; generally relatives or connexions of the ancient "Kutoch" Rajahs of the country. They all have distinctive appellations. One fine canal, which supplies water to four or five villages, is known as the "Daee-jee-ka-Kool," having been constructed at the charge of an old wet-nurse of Rajah Sunsar Chund. Another goes by the name of the "Dubhan Kool," having been made by an old Rajah of that name. This canal, ever since the period of the Goorkha invasion (an epoch to which all disasters of the past are referred) had fallen into disuse. And last year, the people of their own free-will, with the assistance only of a Government chupprassee to collect the labourers, re-excavated the line at their own cost; and restored the waters of irrigation to villages distance twelve miles from the canal head.

Canals how originally constructed.

Another canal of greater fame in this valley is one constructed about 150 years ago by Mean Kirpal Chund, the brother of one of the ancient rulers of the hills. This canal, besides bearing the name of its founder, is emphatically styled by the people the "Dhurm Kool:" and, as its history is interesting, and the canal is one of the finest in the valley, I have selected it to illustrate the peculiar institutions in vogue for the maintenance and preservation of all these canals, and for the economy and distribution of the water.

Kirpal Chund's canal.

The "Dhurm Kool" is taken from the river Niggool, just above the hill village of Bundla. There are four canals whose sources are above, and no less than sixteen canals rising below, the canal head of the "Dhurm Kool." Its length from its source, to the point where its waters become exhausted, is about twelve miles. The exact area it irrigates I have no means at present of ascertaining; but according to the local measurements, it supplies water to two hundred and forty ploughs, each plough averaging about twelve acres, and paying in revenue of about fifty rupees. Thus the whole surface irrigated, may be computed at 2,880 acres, yielding a yearly revenue of about 12,000 rupees.

The people bear the name of Kirpal Chund in reverential memory. He appears to have been childless, and to have devised the construction of this canal as a means of perpetuating his name. His liberality to the people employed was munificent. To each labourer was given six seers of rice, half a seer of dâl, and the usual condiments; and to every pregnant woman employed, he gave an additional half allowance in consideration of the offspring in her womb. The people believe that he still exercises a fostering influence over his canal; and some time ago, when a landslip took place, and large boulders, which no human effort could remove, choked up the bed of the canal, the people one and all exclaimed that no one, but Kirpal Chund could surmount the obstacles. They separated for the night, and the next morning when they assembled to work, the boulders had considerately removed themselves to the sides, and left the canal course clear and unencumbered!

At the canal head there is an officer stationed, who is the hereditary descendant of the man appointed by the founder. He has a water-mill, rent-free, close to the source; and his duty is to look after the embankment, and make any little repairs which the passage of cattle, &c., may occasion.

The official at the embankment. His duties and perquisites.

During the height of the rains, the canal is usually closed. When the rains cease, and a fresh embankment becomes necessary, and extensive repairs are required along the canal course, the people

Repairs of the canal.

are assembled, one from each house which benefits by the canal, and (marshalled by their respective "Koolees" or canal officers,) work in concert until the whole line is restored to a state of efficiency. In former days, any one refusing to contribute his aid to repair the canal was liable to fine by the village authorities; and now that this power is no longer exercised, it is sometimes necessary to lend the assistance of a thannah burkundauz, to collect the people and to set them at work upon the canal.

The village "Koolee" or canal officer.

The "Koolee" is an officer maintained by every village along the line of the canal to look after its particular branch. He is the guardian of the village rights, and sees that the due proportion of water, allotted by custom, for the village use, is fairly given. He patrols along the banks of his own branch, seeing that no water is surreptitiously withdrawn, and none allowed to run to waste. Any breach or damage in the banks, it is his duty to discover and immediately repair. He knows exactly the quantity of land in his village, and the proportion of water which each village is entitled to receive; and according to this scale, he distributes to each man in turn: and, any quarrel amongst themselves is referred to his arbitration and decision. By the old laws, if he succeeded in convicting any man of stealing the water, he was empowered to levy a fine of five rupees to be paid to Government, or to drag the culprit to the village "Koohee" or granary, (for the rents of the valley were formerly always taken in kind,) and to place him in the stocks for a whole day exposed to the public gaze of the village.

Appointment of the "Koolee."

The office of the Koolee is not hereditary. On canals excavated by individuals, the descendant of the founder was allowed the privilege of nominating the "Koolee" on the occasion of a vacancy. On lines constructed by the people themselves, the village appointed its own man; and since our accession, the people have exercised this right on all canals, whether made by themselves or by independent parties. The "Koolee" is usually elected for life. His calling depends upon his honesty and strict impartiality; and he rarely abuses his trust. If he is unfair or unpopular, the people petition for his removal; and I adopt the rule usually observed with regard to other village servants, and allow the majority to dismiss an obnoxious man, and to appoint a successor; but such cases very seldom occur.

The "Koolee" of the main canal.

Besides the "Koolee" for each branch, there is a "Koolee" for the main canal. His duties are the same in reference to the principal canal as those of the subordinate "Koolees" on their respective branches. He patrols along the main line, prevents theft, stops leakage, and looks after the general preservation and economy of the canal. The other "Koolees" acknowledge him as their chief: and not unfrequently he extends his beat to particular branches, and sees that the duties of his "subordinate agency" are properly discharged.

Emoluments.

On the ripening of the spring-crop, the "Koolee" proceeds to collect his dues. Unlike other village servants, who receive a portion from every harvest, his perquisites are limited to the spring; and he receives nothing whatever from the autumn or rain crop:—the reason probably being, that the autumn harvest is matured by rains from heaven, and is less dependent upon artificial irrigation.

Distribution.

He is entitled to receive from every plough of land, (*i. e.*, from every twelve acres of cultivation,) twenty seers, local measure, of wheat; equivalent to about eight seers, according to the standard

weight of India. On this canal, although each "Koolee" collects the dues leviable on his particular branch, he does not enjoy the whole proceeds. The collections, from each cut, are brought to a common fund, and on a given day all the canal officers, including the "Koolee" of the main line, meet at the head-quarters of the canal, and make an equal and arbitrary division of the proceeds: the division not bearing any proportion whatever to the extent of a man's jurisdiction. The average receipts, by each "Koolee" on the Dhurm Kool, amount to about fifteen maunds of wheat a year, or six maunds pucka. The "Koolee" on the main line gets no more than his brethren. All share alike; and apparently they are well satisfied with present arrangements.

On other canals of less extent, there is usually only one "Koolee," who does all the work appertaining to the office; and of course receives all the perquisites.

Distribution of water.

Water appears generally so abundant, that there are no strict regulations regarding its distribution. On most canals, every man is helped in turn to as much water as ever he requires for the saturation of his fields; and probably his turn will recur and find him unmindful of the water at his disposal. On other canals, where the supply is not more than equal to the demand, some little economy is practised. A cultivator will look out anxiously for his turn, and perhaps be tempted to invade the rules. He will probably be limited to a certain quantity of water for a given extent of ground. The common proportion is a cut of eight fingers long, by three deep, for every plough of land. But this is the utmost attempt at limitation. There is no practice of restricting the number of irrigations, or of regulating the supply to the nature of the crop. Each man is entitled to a certain amount of water which he may take until the whole of his land is thoroughly saturated, after which his neighbour enjoys the same privilege in his turn.

By-and-bye, when the settlement records come to be prepared, these unwritten laws must be reduced to record; and precautions taken to provide against that contingency (not far distant) when by the reclamation of new lands the demand for water shall equal and afterwards exceed the present supply. In such a time, a knowledge of the rules in force in less favored localities, such as Nuggeenah in Rohilcund and the Dehra Doon, will serve the district officer in good stead; and enable him through the agency of the village canal officers to introduce many useful reforms, and prevent much contention and fighting.

Mode of procedure on projecting a new canal.

In former days, when a new canal was projected by Government or any influential person, the direction was assumed without any heed to the individual inconvenience entailed. No one ever thought of listening to remonstrances; and the people quite understood the folly of preferring them. Every obstacle had to succumb to the public good: and the line would run through cultivated fields and farm-houses; and all parties would assent to the measure as a matter of course. The Government were expected to remit the revenue on lands taken up by the course of the canal, though they would not allow any compensation for loss of profits. They would also undertake to build another house in the place of the one they had summarily demolished. But they had no idea of postponing or abandoning a public work, because private rights were infringed, or any bold refractory ryut ventured to oppose himself to the general weal.

In canals projected by the people, there were not likely to be objections. Such canals were the results of *bonâ fide* combinations for the general good; and the measure was sure to be thoroughly canvassed and understood before the line was

settled. It was not likely that any cultivator, with the prospect of certain and luxuriant harvests, would refuse to contribute his labour, or demur to the abstraction of a little land. His scruples, if he were a sensible man, would be overcome in a village committee; but, if he was obstinate and deaf to all argument, the people petitioned the Government, and the line was commenced without further delay.

Mode of crossing intersecting canals.

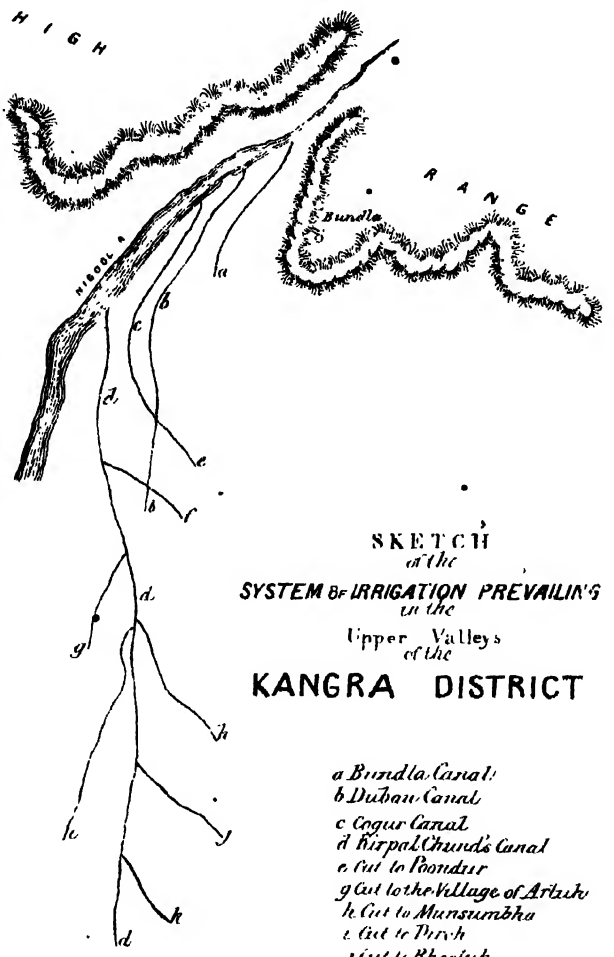
With so many canals intersecting the country, the reader may require to know the arrangements in force when two canals meet. Such a contingency, notwithstanding the multitude of cuts, very rarely occurs; for every canal being destined for a specific village, runs on its course with scarcely any chance of encountering another; and it is only in the case of the longer canals, that lines cross. In such emergencies the people have a ready expedient in building rude aqueducts of long flat stones, which they lay across the lower canal and overlay the stones with clay. On the sides they build up a small embankment of clay, sufficient to retain the water in its rapid passage over the lower cut. Where they cannot get flat stones or slates, they use timber planks; and the water is crossed over without any loss or damage to either line. The country falls so rapidly, and is so undulating, that it is the easiest matter possible to keep one canal on a slightly higher level to the other, and thus to arrange their crossing.

No system of regulating levels.

In this canal of Kirpal Chund, notwithstanding its course of twelve miles, there is no attempt at regulating the levels by the construction of weirs or masonry falls. The canal (and indeed all other canals) simply follows the level of the country in its gradual but rapid descent to the Beas: and the water comes tumbling along with all the noise and velocity of a mountain torrent. One would naturally expect that such a rapid current would soon convert its channel into a ravine; and undermine its way to a level so much below the surface of the country, as to render the water unavailable for the purposes of irrigation. But it is a strange enigma to me, to observe that the canal, although a century and a half have passed since its excavation, still keeps on the surface; and the people experience no inconvenience or difficulty whatever in taking the water. I believe the reason to be, the number of granite boulders thrown off from the lofty chain of hills to the north, which strew the valley in all directions, and of which the under-soil is principally composed. The canal flows, I may say, on a bed of boulders, leaping down one, to dash itself upon another; and by the intervention of these huge masses of rock, is prevented from cutting deep into the soil, as under other circumstances, I presume, it would.

Peculiar privilege of "Dhurm Kool" in construction of embankment.

I should mention, that "the Dhurm Kool" possesses the peculiar privilege of using clay with the stone in its embankment at the canal head. All other canals are restricted to bare stones, through which, of course, a good deal of water escapes. The "Dhurm Kool" alone is allowed to use more tenacious material, and to construct an embankment nearly water-proof. This privilege is jealously insisted on: and I had lately to pay a visit to the canal heads, and to warn the others to use nothing, but the boulders in the river-bed, with a few green sticks to bind the mass together.



SKETCH
of the
SYSTEM OF IRRIGATION PREVAILING
in the
Upper Valleys
of the
KANGRA DISTRICT

a Bundla Canal
b Dubau Canal
c Cogur Canal
d Kirpal Chund's Canal
e Cut to Poondur
g Cut to the Village of Arlah
h Cut to Munsumbha
i Cut to Pirah
j Cut to Rhoolah
k Cut to Mondeh

THE JUMNA CANALS.

Report on the influence of the Jumna Canals on the Jumna River; by LIEUTENANT-COLONEL P. T. CAUTLEY, *Superintendent of Canals, N. W. Provinces.*

Regarding the question as to the effect of the canals on the parent rivers, as navigable lines.

The question—"How far do the Canals on the Jumna influence the capabilities of the river, as a navigable line? or, How far *will* the Ganges Canal, now under construction, affect the Ganges river?" has been frequently asked, frequently discussed, and with no better result, than the parties, who are most opposed to each other, remaining with their original views unaltered.

The only practical illustration on which arguments were grounded.

2.—The only practical illustration of the Jumna Canals not destroying the river as a navigable line, was shewn in cotton boats of a large tonnage reaching Agra, and boats of other descriptions arriving at a higher point of its course, and this too at a period when the Canals carried away the whole of the observable supply of water which it received from the Himalayas. The argument for the Ganges was founded on this fact, and in page 63 of my printed Report, the grounds for my opinion on the effect upon the Ganges, by the Ganges Canal carrying off the whole of the observable Himalaya supply of that river, were given in detail. The argument was perfectly fair, and clearly philosophical. With natural phenomena corresponding, similar results were to be anticipated.

Process by which more precise conclusion could be arrived at.

3.—There remained, however, one process by which we might arrive at more precise conclusions; and this offered itself, in our ability to close the Jumna Canals for certain fixed periods, and by throwing the whole of the water, that formed their supply, back into the parent river, discover, through the intervention of river-gauges, the exact value of increment depending thereon.

Measure sanctioned by Government, N. W. P., and ordered to be carried out.

4.—The Agra Government having warmly approved of the experiment, and directed no time to be lost in carrying it into effect, measures were taken, with the Superintendents of the eastern and western Jumna Canals, to determine on periods of the year, when the test could be best applied, with reference to the object of the enquiry, and at the same time, cause as little interference as possible with the irrigation of crops and the interests of the farmers.

Periods and places of experiments.

5.—With the sanction of Government, the eastern and western Jumna Canals were stopped, and the supply of water thrown back to the Jumna, for four days, at four periods of the year, as follows:

1st Quarter on the 21st, 22nd, 23rd, 24th December 1818.
2nd Quarter „ 1st, 2nd, 3rd, 4th April 1819.
3rd Quarter „ 1st, 2nd, 3rd, 4th June 1849.
4th Quarter „ 30th Sept., 1st, 2nd, 3rd October 1819—

'*Punsals*' or water-gauges having been carefully established, at the following points, on the river below them:

Dehlie, distant from Canal Heads			117½ miles.
Muttra,	ditto	ditto	261½ „
Agra,	ditto	ditto	321½ „
Etawah,	ditto	ditto	451½ „

The registers were kept for a certain time previously to the above dates, and for a period, supposed to be sufficiently extended to admit of the full influence of the Canal supply, afterwards. The registers were to be taken three times a day during the periods noted, and rain-gauge reports, with any other necessary information, were to accompany the returns.

Records kept.

6.—With exception to the registers from Agra and Dehlie, which are imperfect, (the former in the 2nd and 3rd, and the latter in the 1st quarter,) and also from the total absence of that from Etawah during the 4th Quarter, arising from the river-gauge having been washed away, the records, the whole of which accompany this paper, were satisfactorily kept. I find, however, that, *firstly*, sufficient time was not given at Etawah for the effects of the rise of the river being shewn, as exhibited in the 2nd Quarter, when the register terminates precisely at the period when the excess of water was coming into operation; and *secondly*, that no results can be derived from the triple daily measurements. My observations are therefore confined solely to the recorded height of water at 6 A. M. daily.

Note on the 1st Quarter.

7.—A fall of rain in the upper parts of the Jumna valley, as well as at Agra and Muttra, previously to the commencement of the observations for December 1848, is exhibited on the diagram by a defined though slight rise of the river at Dehlie, Agra and Muttra, more indistinctly marked at the Etawah river-gauge. The usual cold weather rains however had not fallen, so as to offer any interruption; so that the diagrams, exhibited on the 1st Quarter of the Table, may be accepted as a very fair test of the experiment.

Dates of closing and opening the Canals.

8.—The Canals were closed, and the whole of the water was turned into the main Jumna at 7 A. M. on the morning of the 21st. On the evening of the 24th December, the river was deprived of this supply, the water having pushed down the main river for four full days.

Effects on the Jumna.

9.—The effect of this additional supply upon the river, appears to have been as follows:—

In	5	days	the Jumna	commenced	rising	on the	Dehlie Punsal.
„	9	„	„	„	„	„	Muttra „
„	11	„	„	„	„	„	Agra „
„	15	„	„	„	„	„	Etawah „

The gradual rise being distributed at each water-gauge amongst four days, excepting at Etawah, where the rise continued for a fifth day.

The total rise on each water-gauge is—

At Dehlie,	15½ inches.	At Agra,	13¾ inches.
„ Muttra,	13¼ „	„ Etawah,	14 „

The rate of progress from

Heads to Dehlie,	29·5 miles per day.
Dehlie to Muttra,	28·5 „
Muttra to Agra,	30·0 „
Agra to Etawah,	32·5 „

or averaging on the whole distance of 451½ miles, an advance of 30·1 miles per day, or 1·85 feet per second of time; equal to 1·254 miles per hour, a rate which, with a section of river like that of the Jumna at this period of the year, may be considered a fair average approximation.

10.—The decline of the river's height, after the maximum point had been gained, appears, in every case, to have been more gradual than the rise, and on the fourth day from the commencement of the decline, the height of the river was considerably in excess to that four days previously to the commencement. In fact the surface of the river, at this period, appears to have been permanently affected by other causes than the Canal supply, as it continued on a higher level than it was when the Canals were closed. It will be observed by the diagram* that at the period when the observations commenced, the Jumna was lower than usual, and the result of the experiment was, in all probability, more conspicuously shewn.

Note on the 2nd Quarter.

11.—The river was affected by rain, or some other cause, previously to the Canals being shut; this is very distinctly shown by the diagram. This affection to the curve is exhibited throughout the whole series of Dehlie, Muttra, Agra, and Etawah, and it gives us another element for determining the progress of the flood water. The effect upon the Jumna, by the shutting of the Canal, is unfortunately not shewn at Etawah; the observations having ceased previously.

12.—In this diagram, however, we have two distinct and well-defined series of curves; the first arising from extraneous causes; the latter from the experiment in progress. In each case there is a remarkable coincidence in the progression of flood as shown by the high water marks; a coincidence common to both the 1st and the 2nd Quarter.

	Dehlie.	Muttra.	Agra.	Etawah.
1st Quarter, -- -- -- Canal flood,	1	5	7	11 & 12
2nd Quarter, -- -- -- Ditto,	1	5 & 6	7	0
2nd Quarter, -- -- -- Extra flood,	1	5 & 6	7	13.

The total rise in this Quarter was,

At Dehlie, -- $12\frac{1}{2}$ inches.
„ Muttra, -- $10\frac{1}{2}$ „
„ Agra, -- $10\frac{1}{2}$ „

The gradual rise to the Jumna being effected in four days at Dehlie, and in only three days at Muttra and Agra; the decline appears to be less rapid than the rise, but the effect upon the surface of the river is a sensible one.

Note on the 3rd Quarter.

13.—The Jumna river was gradually rising at the period when the Canal was closed; whatever effect the Canal supply may have had upon the river, it is not shewn in the diagram; the curve being on the ascendant and continuing, with little variation, on the ascendant throughout.

Note on the 4th Quarter.

14.—Here the Canal supply has no effect upon the surface of the Jumna river, which is rapidly on the descendant.

15.—From the above observations, and from the curves of the diagrams which accompany these, I draw the following conclusions :—

Deductions.

1*st*.—That the higher the water is in the Jumna, the less is the surface of the river affected by the water taken away from it by the Canals.

2*ndly*.—That the Canals only affect the surface of the Jumna river when that river is low, *i. e.*, during the cold, and the early part of the hot weather; especially in the early part of March.

* *Vide* Appendix.

3rdly.—That the maximum affection occurs in the latter part of the cold weather, and in the early part of March; and that the rise of surface, noted in the diagram of the 1st Quarter, of from $15\frac{1}{4}$ to $13\frac{1}{2}$ inches, in December and January 1818-19, may be considered a fair maximum effect upon the river during those months.

Were boats sticking upon a sand bank, or on the top of a rapid, the above rise of surface would, in all probability, relieve them; but it is questionable whether, using the term "navigable river" as usually applied, the Jumna (considering the wide expanse of its bed, and the numerous shoals that distinguish its course, from the Himalayas to its junction with the Chumbul below Agra) would, with the additional rise of surface above noted, be more favorably open to navigation than it is at present.

16.—At any rate the above observations confirm the assertions that have been made before, that the subtraction of a supply for the Canals only effects the Jumna river during three months in the year, that is, from the middle of December to the middle of March; at which latter period the melting of the snow in the mountains has a visible effect upon the river.

PART II.

PONTOON BRIDGE.

Remarks by CAPTAIN J. N. SHARPE, *Executive Engineer, on a Pontoon Bridge, constructing at Agra, under the Superintendence of* MR. C. C. JACKSON, *the Magistrate, (with Estimate and Plan.)*

SPECIFICATION.

Before detailing the description of Pontoons proposed for this Bridge, I should state that three of them have already been prepared under the superintendence of Mr. C. C. Jackson, the Magistrate of Agra, formed into a raft and inserted in the body of the present bridge of boats, and thus having been submitted to actual trial by passing over them the whole of the captured Seikh Ordnance, may be considered to answer their intended purpose; the specification will therefore be confined to a description of the original design as carried out by the Magistrate, and the estimate framed upon it, with a few observations from myself of any improvements which a consideration of the subject may have suggested.

2.—The Pontoons as constructed are cylindrical in shape, with conical ends, the semi-axis being 4 feet; the diameter of the Pontoons is 5 feet 8 inches, the length of the straight portion is 22 feet, making the total length 30 feet. The Pontoon is composed of sheet iron from one-eighth to three-sixteenths of an inch thick. The plates well rivetted and the interior trussed with iron tires or rings at every sheet of iron. A man-hole is provided for examining the interior and pumping out water.

3.—The centre and two extreme baulks or beams supporting the roadway lie upon saddles bolted to a trussed framing within the Pontoon, as shewn in section, the upper and lower pieces of which are kept in position by two uprights, tightened by wedges. The saddles are composed of 4 pieces of wood firmly bolted together, 14 inches in thickness, and rising 12 inches above the top of the Pontoon. The baulks or beams which rise in the saddle are composed of two pieces, measuring 8 by 22, and one of 3 inches square bolted into the saddle. The intermediate beams, which are 2 by 8 inches, are let into cross pieces mortised into the principal beams.

4.—The Pontoons are 18 feet from centre to centre, apart; the roadway 25 feet in width composed of 2 inch fir planks nailed down and covered with an inch of earth, kept in its place by side pieces. The roadway to be protected by a railing of light chain, on posts fixed at intervals of 6 feet.

5.—As already stated, three Pontoons of the above dimensions have been made and inserted in the body of the bridge, in which state they draw about 2 feet 10 inches of water, and as it does not seem advisable that the centre of each Pontoon should be depressed more than 6 inches under any load that may be brought upon

the bridge, (in which case it would draw 3—10 inches) the load that would depress it down to that level would be about 10,000 lbs. Now, the roadway being 25 feet in breadth, and the Pontoons 18 feet from centre to centre, this weight would give about 22 lbs. per superficial foot. The greatest load which could be brought upon the bridge would be about 70 lbs. per superficial foot, and as it may not be possible at all times to prevent a rush or crowd of people upon the bridge, it seems scarcely prudent to trust to so small an amount of floatage per superficial foot. I would beg therefore to suggest that the distance between the Pontoons be reduced to 16 feet, and the roadway to 18 feet in breadth, which would give 35 lbs. per superficial foot of floatage.

6.—The principal beams of the roadway have been made in three pieces for the sake of economy, but I think that single pieces of 8 by 6 inches would be in every respect preferable, and instead of the weak support given to the intermediate beams, I would recommend saddles as for the principal beams; if the central distance between the Pontoons should be reduced to 16 feet, beams would be of sufficient scantling if only $7\frac{1}{2}$ by $4\frac{1}{2}$, and I would make the saddle and trusses only $4\frac{1}{2}$ or 6 inches thick, preserving the bays by intermediate pieces; this could not add much to the weight of the framing, and when the Pontoons take the ground they would be better able to support, without injury, the load passing over them. The planking, which is of fir, would, I consider, be better if $2\frac{1}{2}$ inches instead of 2 inches.

7.—From the changing state of the river, it is obvious that no determinate part of the bridge can be fixed upon for the passage of the river traffic; it seems therefore desirable that the central intervals of the Pontoons should have some reference to this object, so that the passage may be made in any portion of the bridge. From a measurement of the largest boats in the river it would appear that 26 feet could be a sufficient opening in the bridge; now a raft of 3 Pontoons would at 18 feet interval allow of 30 feet, and at 16 feet would give an opening of 26 feet, and whichever may be adopted, a passage may be easily effected by making the raft about 4 feet less than the layer opening, and making that portion of the roadway occupying the interval between the raft and the bridge to fall back by hinges.

8.—The causeway for approaching the bridge on either side may be similar to that already made on the Agra side of the river, but it should be of sufficient length to be made use of at the highest and lowest levels. The causeway, above-mentioned, is composed of grooved stone slabs, and has a slope of 110 feet, it would therefore require to be 120 feet long; the difference between the highest and lowest level being 12 feet. It would be more convenient to remove the Pontoons floating over the causeway, before they strike the ground, and the small distance to be gained between the first Pontoon and the causeway may be managed by a platform, the beams supporting which should hook on the Pontoon, the other end resting in rollers, the platform will thus of itself change its inclination as the river rises or falls within the limit of floatation of the Pontoon to which it is attached.

9.—I have described the means of opening the bridge and approaching it from the shore, because I had not been made acquainted with the Magistrate's views on this subject; and, as the means are various, it is probable that he may decide upon a more efficient mode than I have suggested.

The length of bridge required is about 1,242 feet, giving 68 Pontoons at 18 feet apart, and 77 at 16 feet.

ABSTRACT.

Estimate of Cost of Pontoon Bridge.

50 maunds of Sheet Iron,	--	--	--	--	--	371	6	10			
10 ditto of Bar Iron,	--	--	--	--	--	200	0	0			
Labor of making up,	--	--	--	--	--	480	15	2			
450 square feet of roadway,	--	--	--	--	--	376	3	0			
									1,128	9	0
Add 5 per cent. Contingencies,	--	--	--	--	--	--	--		71	7	0
									1,500	0	0
Add for 67 more,	--	--	--	--	--	--	--	--	--	--	1,01,500	0	0
									1,03,000	0	0
If at intervals of 16 feet add for 9 more,	--	--	--	--	--				13,500	0	0
Grand Total, Company's Rupees	--	--							1,16,500	0	0

PONTOON BRIDGE* AT AGRA.

Report of the Committee appointed by Government to report on the IRON PONTOON BRIDGE, *on the River Jumna at Agra, viz.,* C. ALLEN, ESQ., C. S., *President,* MAJOR W. PILLANS, *(Artillery,)* CAPTAIN J. R. OLDFIELD, *(Engineers,) and* CAPTAIN J. A. WELLER, *(Engineers,)* Members.

(To which is appended a Memorandum regarding the Bridge of Boats at Dehlie, by A. A. Roberts, Esq., C. S.)

Description.—The Bridge over the Jumna at Agra consists of 70 Pontoons placed at central distances of 17′ : 8″ apart, and is thus 1,256 long.

2.—The Pontoons are hollow cylinders of sheet iron, their length is 30 feet, including the ends, which are nearly paraboloids, with axis 4 feet in length, the cylindrical portions being 22 feet long, with a diameter of 5′ 7″ 6.

3.—The two end Pontoons of the Bridge, and the two bearing the raised platforms which form the opening, are similar in form, but of greater length.

4.—The roadway is formed of part saul and part fir wood planking, 2″ thick, supported by three main beams bolted by double bolts into saddle pieces, which are themselves firmly fixed to the Pontoons, by bolts passing through the iron shell of the Pontoon, and secured to trussed wooden framings within it. Between these main beams, slighter beams are framed to give intermediate points of support to the planks of the roadway.

5.—*Principle of Construction.*—The advantages and disadvantages, of close cylindrical vessels with conical ends as Pontoons, have been treated of at length by Sir Howard Douglas in his treatise on Military Bridges. He objects principally to their instability; and the form of their prows, when submerged, arresting any floating bodies which may be brought down to them by the stream.

6.—The first of these objections has been met in the Agra Bridge, by the unyielding nature of the superstructure, which has been formed by bolting each end of every main beam with two bolts to the saddle of the Pontoon.

7.—This plan, of forming a very rigid and nearly inextensible roadway, has the disadvantage of rendering it difficult to take the Bridge to pieces, as the strain on the bolts so binds them, that they cannot be extracted after having been some time in use, without injury either to the bolts or beams of the structure.

8.—*Steadiness under passing traffic.*—This rigidity of the roadway has the effect, however, of rendering the undulations of the Bridge, under passing loads, very trifling; an advantage which would amply compensate for any extra wear and tear incurred, or strength required thereby, if the Bridge was one which continued to float throughout the year.

9.—The Jumna seldom brings trees or other floating bodies down to Agra, or it would certainly be advisable to raise the prows of the Pontoon above the line of greatest immersion.

10.—The chief advantage of the cylindrical Pontoon is, that its form opposes the smallest resistance to the stream in proportion to the weight it will bear.

11.—A disadvantage at Agra, or in any river subject to become shoal, is the depth of the parts immersed, in proportion to the breadth, which causes the cylindrical Pontoons to take ground much sooner than if they were boat shaped.

* *Vide* Vol. 2nd, page 61.

12.—*Buoyancy.*—The buoyancy of the Agra Bridge seems to be quite sufficient for the traffic, (*vide* Appendix A.) No ordinary loads are more than 30 lbs. per superficial foot of roadway; or 12,720 lbs. (about 155 maunds) on the surface of roadway supported by one Pontoon: and as the rigidity of the structure of the roadway distributes the weight placed on any Pontoon on at least two others, the actual depression, unless the adjoining ones were equally weighted at the same time, would be considerably lessened, perhaps to that due to only half the weight passing over.

13.—Considering the Pontoons as cylinders 22 feet long, and averaging in diameter 5′ : 76″ (for they vary slightly) and their ends as paraboloids 4 feet long, the total buoyancy is 39,875 lbs. The weight of the Pontoon, found by means of weighing its component parts in the scales, is 5,529 lbs.

14.—The depth, at which an unloaded Pontoon floats freely, was found by trial to be 14·125 inches, whilst the weight due to this immersion is by calculation 5,562 lbs.

15.—The weight of the roadway may be taken at 7,942 lbs. found by counting and weighing the iron, and measuring the wood work; taking the specific gravity of Saul at 893, and of Deal at 640.

16.—These specific gravities were obtained by actual weighing of specimens of wood used in the work.

The weight of the Pontoon, -- -- -- -- -- --	5,529 lbs.
Added to the weight of a portion of roadway 21×17′ : 8″ :	7,941 „
Equal,----	13,473 lbs.

which is rather more than equivalent to an immersion of 25 inches. A weight of 6,464 lbs., or about 79 maunds, in addition to this, would immerse the Pontoon to half its depth, and twice this weight would immerse it nearly 9 inches more, and this being equivalent to 158 maunds, or about 30 lbs. per square foot of roadway, may be considered as the limit of ordinary traffic.

17.—A crowd of people, densely packed, is estimated to weigh 7 ' lbs. per square foot. A less weight than this, or about 60 lbs. per square foot, would bring the roadway to the water's edge; but besides that such an occurrence ought never to be allowed, there would be little danger even if it did, as then the superstructure would itself float, and bear the increased weight.

18.—*Durability and method of moving the Pontoons about, and adapting the Bridge to the differing states of the River.*—This is principally affected by the oxydation of the metal. This is greatest in those Pontoons which rest on the wet sand of the river bed. Indeed, so great is it in this situation, that it is essentially necessary that means be taken either to prevent it in part, or to support the Bridge on piles for half the year, and this would perhaps be the most eligible plan, but for the difficulty of taking the roadway to pieces, and re-constructing it, for though so long as the Pontoons float, it is easy to depress them singly, and detach them from, or attach them to, the roadway; after they have become bedded in the sand, they are very difficult to remove, and to replace them would be still more difficult.

19.—Suppose them taken away, it is evident that it would not be safe to wait for the rising of the river before replacing them, as it might very probably rise too rapidly, from the level at which the Pontoons would float, to that at which the roadway was supported by piles or stanchions. But for their oxydation, the Pontoons would make excellent piers.

20.—The prevention of this evil is a practical problem, which must have received the attention of all persons concerned in the construction of iron ships; and application should be made to the dockyard Engineers of Calcutta, for information regarding the most approved precautions for preserving iron in contact with moisture. Perhaps in the present case, Sir Humphrey Davy's suggestion of inducing Galvanic agency, by the application of copper and zinc plates to the boats in contact with the stream or wet sand might prove applicable.

21.—The oxydation of the iron, so long as it remains in running water, does not appear to be considerable, and is fairly met by a liberal use of Coal Tar, though perhaps plates of zinc would be the cheaper preservative, especially as their renewal would not render necessary the removal of the Pontoons.

22.—*Opening for the passage of Boats.*—The method that has been adopted to give an opening in the Bridge for passing vessels, is by means of a raft of two Pontoons made longer than the rest; on either side of which, a platform is made, movable on hinges, so as to connect it with the remainder of the Bridge on either side. These platforms are raised by means of an apparatus, consisting of ropes passing over two standards erected on the movable raft, and worked by a windlass assisted by pullies.

23.—This plan of opening the Bridge is rather more complicated than the usual one of having a Pontoon at each end of the movable portion, and probably more difficult of management in a strong current; it has the advantage however of floating on a narrower base, and being therefore well adapted for a narrow stream; and in the Jumna there might not, in the dry season, be width enough of stream capable of floating three Pontoons, at 18 feet intervals, and also of drawing them up on one side, which would require a stream of 72 feet wide, and $3\frac{1}{2}$ to 4 feet in depth.

24.—In consequence of the manner in which the superstructure is put together in its length, any change of place in the opening would be attended with much expense and delay, as no portion of the roadway can be taken to pieces, without almost wholly breaking up such portion.

25.—*Suggestions for improvements in Construction.*—A defect in the carpentry of the roadway must also be noticed. The planking is supported by three principal beams, placed at 9 feet apart; these spaces are fitted with intermediate beams, put together in the same plane, by means of mortises in cross beams, attached by iron plates, bolts and screws to the principal beams: the whole of this framework is exceedingly weak, with a great and useless expenditure in bolts, nuts and iron plates.

26.—Two additional main beams would obviate the necessity of any intermediate framing. These main beams are each of two pieces $8\frac{1}{2}$″ deep and 3″ broad with an intermediate piece only 4″ deep. This middle piece, besides adding to the total width of the beam, is useful for nailing the planking to; thus saving the principal beams from injury from this cause, which is a clever and economical expedient.

27.—*The actual cost of the present Bridge.*—The estimate was Rs. 1,500 for each Pontoon, complete with roadway, and it has not been exceeded. Seventy Pontoons have been finished; of these six are of extra size, viz. four for the two kulfies (or water ways for boats,) and two for the extremities of the Bridge, to receive the first shock.

28.—The statement submitted by the Magistrate to Government, in October 1847, shows an actual expenditure of Rs. 1,18,062-10-5 to the end of September; since then, during the months of October and November, Rs. 5,163-9-11 were spent, which gives a gross total of Rs. 1,23,226-4-4, to the completion of the Bridge.

29.—From this must be deducted a sum of Rs. 2,500, advanced for the building of the Ghauts, and the value of the materials on hand; or Rs. 12,366-12-4. In the abstract appended to the Magistrate's statement, they are estimated at Rs. 14,293-3-10; but Mr. Mackenzie reports that materials to the value of Rs. 1,926-7-1 have, during October and November, been expended.

Iron lost on the River, ...	716 7 4	
Deal Timbers, ...	1,120 0 0	
Nails, ...	140 0 0	
Coal Tar, ...	100 0 0	
	2,076 7 4	
Deduct refuse wood, under estimated in abstract, ...	150 0 0	
	1,926 7 4	

30.—There are items to the value of Rs. 11,441, classified in this abstract as "items not estimated for;" but with the exception of Rs. 2,500 advances for the Ghauts, they appear to the Committee as fairly forming part of the cost of the Bridge; for instance, the expense of building workshops has been included, because they were necessary, and will be, for the repairs of the Bridge.

31.—The actual cost of the Bridge has therefore been Rs. 1,08,359-8-0.

The items unpaid for, are the pullies and ropes necessary for working the kulfies, and iron cables for anchoring the Pontoons, should such be used. Compare this with the estimate;—70 Pontoons, at Rs. 1,500 each, would cost 1,05,000:—the surplus of Rs. 3,359 is only a fair set-off against the extra size of six Pontoons.

Gross expenditure, ...	1,23,226 4 4	
Deduct advanced for Ghauts, ...	2,500 0 0	
Materials on hand,	12,366 12 4	
	14,866 12 4	
	1,08,359 8 0	

32.—The Rs. 1,500 estimated for each Pontoon appears to have been divided nearly in the following proportions:—

	For one.	*For all.*
Sheet iron,	390 × 70 =	27,300
Other description of iron,	210 × 70 =	14,700
Manufacture of iron, including cost of Coals and Charcoal, &c.,	500 × 70 =	35,000
Timber,	300 × 70 =	21,000
Labor on wood work,	100 × 70 =	7,000
	1,500	1,05,000

Now classifying the actual cost in (as nearly as may be) the same divisions, we have—

Sheet Iron,	37,635 12 3	
Other descriptions of Iron,	13,488 1 6	
Labor on Iron work, &c.,	24,809 12 10	
		75,933 10 7
Timber,	26,003 8 0	
Labor on wood work,	9,851 5 4	
		35,854 13 4
Establishment,	2,729 8 7	
Miscellaneous,	6,208 3 10	
		8,937 12 5
Total,		1,20,726 4 4
Deduct value of Materials,		12,366 12 4
Rupees		1,08,359 8 0

33.—The cost of the roadway is more than the Rs. 35,854-13-4 classified under timber; and the cost of the iron Pontoons themselves, is less than the Rs. 75,983-10-7 classified under iron; for a considerable quantity of costly iron work has been expended on the roadway.

34.—*The probable cost of any other Bridge which may be hereafter constructed on the same, or on similar principle.*—The cost of any other Bridge, constructed on a similar principle, will probably be considerably diminished. For instance, the sudden and large demand for sheet iron in the bazar, raised the price fully 15 per cent., and this was the heaviest item of expenditure. The prices of other articles at different times are not so easily compared, but most of them apparently increased in price as the demand became large. The experience gained, too, must facilitate the workmanship, and lessen the labor. Again, as has been explained above, the roadway has been constructed on an erroneous principle, and the suggested improvements in carpentry will diminish the cost of the wood work, and will almost entirely supersede the iron work, much of which is very costly, in the roadway.

35.—*Suggestions for reducing the Cost.*—The cost would be reduced very considerably, by adopting the suggestions for lightening the Pontoons, and for improving the roadway, and by purchasing the raw materials, particularly the iron and timber, at the cheapest marts. The market here is too small to supply any large quantities of such raw materials, without a considerable enhancement of price.

36.—*The cost of maintaining the Bridge, the establishment necessary for keeping it in repair, and working it.*—Mr. Jackson proposes, for these purposes, an establishment, as given in the margin*. This may be deemed sufficient for working the Bridge, but the Committee think it is impossible to give any accurate estimate for keeping the Bridge in repair; for that must depend entirely on the durability of the materials, which experience alone can decide.

* ESTABLISHMENT.

For Repairs.

8	Blacksmiths, ...	40
1	Head man, ...	25
11	Carpenters, ...	72
		137
	Materials, ...	100
		237

For working the Bridge.

Superintendent's Commission, ...	100
Chuprassees, Mullah, Gomashtah,	154
Contingencies, ...	65
	319

37.—*The durability of the materials of which it is constructed.*—The iron Pontoons, if the corrosion could be obviated, would last for very many years, requiring little or no repair. The wood work has great strain upon it, and will apparently require constant and expensive repairs, but this question of durability has been adverted to in other parts of the report.

38.—*The probable average annual expense of renewing the materials.*—The articles which will require renewing altogether within the year, or oftener, are, cables for mooring the Pontoons, ropes for raising the platforms of the kulfies, and Coal Tar for applying to the Pontoons. The cost of cables during the last year was Rs. 485-13-0, the cost of Coal Tar Rs. 658-14-0. The ropes of the kulfies have not yet been paid for, nor is it known how frequently they will require renewing within the year. Mr. Jackson also proposes to substitute iron cables and chains, for the ropes, which, if carried out, will of course obviate those annual items of charge.

39.—*Suggestions for reducing the probable cost of maintenance.*—The Committee have nothing further to say on this point.

40.—*The comparative advantages of an Iron Pontoon Bridge, over an ordinary Bridge of Boats as to ease of passage, economy, and other considerations which should decide a preference.*—The advantage of the Pontoon Bridge, as to ease of passage, consists in the superiority of the roadway constructed. With Pontoons, which are light, it was necessary to make the roadway rigid, whilst heavy Boats oppose so

great a resistance to the weight of passing traffic as to permit of the roadway being joined in a more flexible and economical manner. At the same time, should this extreme rigidity be desired, a similar framework, and roadway, could be applied with greater ease and less expense to Boats, than to cylindrical Pontoons.

41.—As regards economy, the whole question hinges on the durability of the Pontoons, and the ease with which the roadway can be applied to Pontoons. The price of Boats, in the first place, is less than that of the Pontoon, but that may be counterbalanced by the greater durability of the latter.

42.—In a valuable memorandum of the cost of the Dehlie Bridge drawn up by Mr. Roberts, and forwarded with this, (See Appendix B.) it is said seventeen Boats built in the Hills, cost Rs. 450 each, while one built at Dehlie, cost Rs. 665, and the price of the platform between the Boats is Rs. 144. The length of one Boat and platform is above 27 feet, *i. e.*, as 3 to 2, compared with a Pontoon and roadway. The cost of a Boat and platform, taking the Boat built at Dehlie, which is the dearest, is Rs. 809, while a Pontoon is Rs. 1,500.

43.—The first cost of a Pontoon Bridge, as compared with a Bridge of Boats, built with platforms between each Boat, is therefore, as (1,500×3 or) 4,500, to (809×2, or) 1,618; in other words, the first cost of the Pontoon Bridge may be taken at two and three quarter times that of a good Bridge of Boats; were the platform of the Boat and the roadway, made of better materials, and equal in rigidity and every other point to those of the Pontoons, the first cost would be perhaps nearly half that of the Iron Bridge.

44.—With regard to annual repairs, it is difficult to form a comparison, but it may be assumed that it would be nearly equal. In the *roadway* the Boats would have a slight advantage, for the lightness of the Pontoons would cause a greater strain on the framework: and in the *Boats* themselves, the cost of coal, tarring and removing the Pontoons, would for some years probably equal any repairs that new Boats would require.

45.—Except in the particulars mentioned, the Pontoon Bridge as executed at Agra, may be considered as admirably adapted for a rapid river, which never, falls so low as to allow the Pontoon to rest on its bed, whilst for Agra, it may be thought that a more boat-like form of support would be better adapted, as drawing less water, though opposing a greater resistance to the stream in proportion to its buoyancy, than the cylindrical form.

46.—As regards material, the question resolves itself into one of first cost, and comparative durability, and for this last comparison we have no data; whilst even for the first, the data are imperfect, as by using an uniform thickness of iron, and dispensing with the greater part of the iron work of the roadway, a very great saving would be made in the construction of a second Bridge; perhaps as much as one-third of the total cost.

47.—It may be added that iron is becoming every day cheaper in India, whilst wood is becoming dearer. The ordinary tables seem to show that their weight and strength are very nearly in inverse proportion to each other.

48.—The Committee cannot separate, without recording their sense of the admirable manner in which the Pontoons have been constructed, reflecting as it does such credit upon Mr. Jackson, and the working Engineer, Mr. Mackenzie. The Pontoons, some of which have been in the river nearly two years, were all as well rivetted, and water tight, as when first launched into the river; and there is no Floating Bridge in the country, which can be compared to the Agra Bridge for elegance of structure, or for the ease and rapidity with which the passage can be made.

APPENDIX A.

A. (1.) The Pontoons may be considered as cylinders, each 22 feet in length, and averaging 5′ : 7·6″ in diameter, their ends being paraboloids, with an axis or length of 4 feet.

The greatest buoyance, or weight of water displaced by one such Pontoon, is 39,875 lbs.

With an immersion of	14·185	inches	it is	-- --	5·562
With ditto of	25	ditto	it is	-- --	13·333
With ditto of	33·8 or ½	diam.	it is	-- --	19·937
With ditto of	42·6		it is	-- --	26·542
With ditto of	53·125		it is	-- --	34·312
With ditto of	67·6 or whole	diameter	it is	--	39·875 lbs.

By experiment, it was found that a Pontoon floating freely, drew 14·185 inches.

A. (2.) The weight of a Pontoon, found by weighing its component parts, is as follows:—

36	sheets of iron ca. 6′ × 2′ × $\frac{3}{10}$ wg.	95 lbs. each, --	3,420
28	bent pieces forming ends	do. 41 lbs. 6 oz. ea.	1,151½
12	inner ribs ea. 17·5′ × 2¾″ × ¼″	do. 39 lbs. 10 oz. ea.	475¼
2	circular plates @ ends 8″ diam.	do. 3 lbs. ea.	6
1	circular end for fastening rings, 39—12		
1	ditto ditto, -- -- -- -- --21— 4		61
1	end ring and bolts, -- -- --17— 4		
1	ditto ditto, -- -- -- -- -- 2—12		20
Lead, -- -- -- -- -- -- -- -- -- -- -- --			7
3	Wooden frames inside,-- --	ditto--55 lbs. each -- --	165
			5,529;

agreeing very nearly with the weight calculated as corresponding with the observed immersion. The pieces of iron weighed, were selected by the constructor of the Bridge as affording a fair average; very various thicknesses of plate, and forms of bar in the ribs, having been necessarily used, because there was no choice in the market.

Iron plate ⅛″ in thickness and ribs of iron bar 1½″×¼″ would have been sufficiently strong; the cost would thereby have been much reduced, as well as the weight; this last by ⅓rd, or 1,842 lb., and the power of the Pontoon increased to an equal amount.

A. (3.) The area of the portion of roadway supported by each Pontoon is 17·8′ × 24′ or 424 feet. The weight of this portion, found by measurement of the wood work, and weighing cubes of both the Saul and Deal Timber used therein, also by counting and weighing the various bolts, &c., is 7,944 lb., as per following details:—

	No.	Length	D.		B.	
Beams, -- --	6	× 12′	: 2″ ×	8½″ ×	3	= 1861·5
	3	× 12	: 2 ×	4¼ ×	3	= 465·37
	4	× 12	: 2 ×	3 ×	8	= 1241·
	4	× 9	: 6 ×	8 ×	3	= 969·
Plants, --	12	× 17	: 8 ×	2 ×	13½	= 5724·
Side Pieces, --	6	× 17	: 8 ×	1½ ×	6	= 954·
Posts, -- --	6	× 3	: 3 ×	7¼ ×	6¾	= 257·25
				2	2	
Saddles, -- --	3	--	--	--	--	3,009·72
Ditto, -- --	4	--	--	--	--	927·92
						15,409·76, or 107· cubic feet of Saul.

N. B.—Saddles.

No.

$\frac{3 \times 4\frac{1}{2} + 3\frac{1}{2}' \times 9'' \times 14''}{2} = 1512$

D. D.

Segments.

$3 \times 11{\cdot}09 \text{ --} \times 14'' = 465{\cdot}78 = 1046'22$

$3 \times 5\frac{1}{2}' \text{ --} \times 8\frac{1}{2} \times 14'' \text{ ---------- } 1963.5 = 3009{\cdot}72$

$\frac{4 \times 4\frac{1}{2} \text{ --} \times 3\frac{1}{2} \times 9'' \times 3''}{2} = 432$

$4 \times 11.09 \times 3 = 133{\cdot}08 = 298{\cdot}92$

$4 \times 6' : 2'' \times 8\frac{1}{2} \times 3 \text{ -- -- -- -- } 629 = 927{\cdot}92$

Add Fir Planking.

No.

$12 \times 17' : 8'' \times 2'' \times 11'' = 4664 \div 144 = 32{\cdot}4$ cubic ft. of Fir.

Weight of Saul $107{\cdot} \times \frac{893}{16} = 5972$

of Fir $32{\cdot}4 \times \frac{649}{16} = 1296$

of Iron, -- -- 676

Total Weight of Roadway, -- 7944 lbs.

Detail of Iron.	M.	S.	B.	T.	Weight. lbs.	oz.	Total.
Bolts, -- -- -- --	6″	2′	1⅛″	1⅛	11 :	12	··· 70 : 8

	No.	L.				Weight.		Total.
Bolts, with Nuts, -- -- --	6	× 2′	× 1⅛″	× 1⅛	= lb	11 : 12	--	70: 8
Ditto, ditto, -- -- -- --	6	× 1	× 1¼	× 1¼	= lb	6 : 1½	--	36: 9
Ditto, ditto, -- -- -- --	21	× 1½	× 1⅛	× 1⅛	= lb	8 : 12	--	183: 12
Ditto, ditto, -- -- -- --	47	× 1	× ⅝	× ⅝	= lb	1 : 7½	--	69: 0½
Ditto, ditto, -- -- -- --	12	× ¾	× ¼	× ¼	= lb	1 : 3	--	14: 4
Nails, -- -- -- -- --	391	@ per 20	----		= lb	3 : 4	--	66: 3
Bars, -- -- -- -- -- --	8	× 3′ : 5″	× 2 ″	× ¾″	= lb	13 : 4	--	106: 0
Ditto, -- -- -- -- -- --	4	× 3′ : 0	× 2½	× 1/16	= lb	8 : 12	--	35: 6
Ditto, -- -- -- -- -- --	16	× 1 : 4	× 2	× ½	= lb	4 : 9½	--	73: 8
Ditto, -- -- -- -- -- --	4	× 0 : 11	× 3¼	× ½	= lb	5 : 6	--	21: 8
								676: 5½

APPENDIX B.

Memorandum regarding the Bridge of Boats at Dehlie.

During the rains the main stream of the river is 585 yards broad at the Bridge of Boats.

Seventy-seven boats, and 52 double platforms, constitute the Bridge in the rains.

During the dry months it is necessary to bridge 513 yards, which takes 66 boats and 47 double platforms. The water covers but 178 yards, in which there are 23 boats and 17 double platforms. The remaining 335 yards are sometimes dry, and sometimes (especially about this time) under water, and in this part there are 43 boats and 30 double platforms. Plans of the boats and platforms are annexed.

There is a double roadway railed off on either side. Travellers and conveyances going from east to west are kept on one side, and those from west to east on the other. There is a *pair* of platforms between the boats, with a few exceptions. Only 18 boats belong to Government, the rest are hired, at Rs. 10 a month each, for which the owner provides a boat and a mullah to each boat.

Seventeen of the Government boats were built in the Hills some years ago, and cost Rs. 450 each; one boat was built in Dehlie, and cost Rs. 665; a pair of platforms cost Rs. 141. It is difficult to form an accurate idea of the annual charges of a Bridge of Boats.

Until 1846, and again in 1847, during both which years the Bridge was maintained throughout the rains, it was almost an annual occurrence for the Bridge to be carried away once at least in the year, and the expense of putting it together again very great. Here however are the receipts and disbursements for three years.

Years.	*Receipts.*	*Total Disbursements.*	*Establishment.*	*Hire of Boat.*	*Materials, Wood, &c.*	*Money for Cables.*	*Repairing Roads.*	*Miscellaneous.*
1844-45,-- -- --	39404	21767	3885	5602	1438	5469	2879	3492
1845-46,-- -- --	32957	26764	4191	6224	3238	4734	3961	3814
1846-47,-- -- --	32061	20083	4196	1378	1923	3647	2925	2714
Average, --	34807	22871	4390	5351	2199	4616	3255	3006

It will be seen, that full two-thirds of the annual receipts are expended, and but one-third carried to the credit of the Ferry Fund. This large outlay can easily be accounted for. The Magistrate, who has charge of the Bridge of Boats, is required to maintain the communication between Sulcimpoor on the left bank, and the city of Dehlie on the right, the distance is full two miles over low sandy ground. At the height of the rains, there is scarcely a foot of dry ground, as the river spreads from bank to bank, and during the dry months, there are generally three streams: first the escape cut of the Canal; secondly, the main stream of the river about midway; and thirdly, a small stream immediately under the walls of Dehlie.

In the rains it is necessary to ferry the passengers and traffic from Dehlie to the main stream. This is crossed on the Bridge of Boats, and if the floods are high, recourse must be had to the ferry from the other side of the Bridge to Suleimpoor. In the dry months it is necessary to keep up a bridge of 6 or 8 boats across the stream near the city, and another over the escape cut, besides this, the heavy sand from the city to the great bridge, and from this to Suleimpoor, has to be made passable by jhao grass, &c., being spread, and the sand cleared away. All these matters must be taken into consideration when comparing the cost of the Bridge of Boats at Dehlie with similar works.

FLOATING BRIDGES.

Comparative advantages of the Bridge of Boats at Dehlie, and of the Pontoon Bridge at Agra.*

Government Order, communicated by W. Muir, Esq., *Secretary to Government, North Western Provinces, to* M. R. Gubbins, Esq., *Magistrate of Agra, dated 14th July 1852.*

Sir,

The Honorable the Lieutenant-Governor is desirous to institute a comparison between the floating bridges over the Jumna at Dehlie and at Agra, of which the former rests on country boats, and the latter on iron pontoons. Both of these bridges have been maintained throughout the year for some years past, and they are situated on great lines of traffic near large cities, they afford therefore a good opportunity for comparing the two modes of maintaining a communication across the river.

2.—You are intimately acquainted with the two localities and with the history of the two structures. In 1842-43, as Officiating Magistrate of Dehlie, you had charge of the Bridge of Boats there, and as Magistrate of Agra paid much attention to the iron and pontoon Bridge here. I am therefore desired to forward to you the annexed† rough statements of receipts and disbursements at the Dehlie and Agra Bridges during the years from 1848 to 1851, both inclusive, and to request that you will favor the Government with your opinion on the comparative merits of the two structures. You will be able from the records of your own office at Agra, to obtain any further information that may be requisite regarding the bridge at Agra, and Mr. A. A. Roberts, the Magistrate at Dehlie, will readily furnish you with any particulars you may wish to ascertain regarding the bridge at that city.

3.—It is desirable that the two structures be compared with reference to convenience of transit and economy of construction, so far as the experience of the last few years affords grounds for the formation of an opinion.

No. II.—*Report dated 23rd July 1852, by* M. R. Gubbins, Esq., *Magistrate of Agra, addressed to* W. Muir, Esq., *Secretary to Government, North Western Provinces, in reply to Government Order dated 14th July 1852.*

Sir,

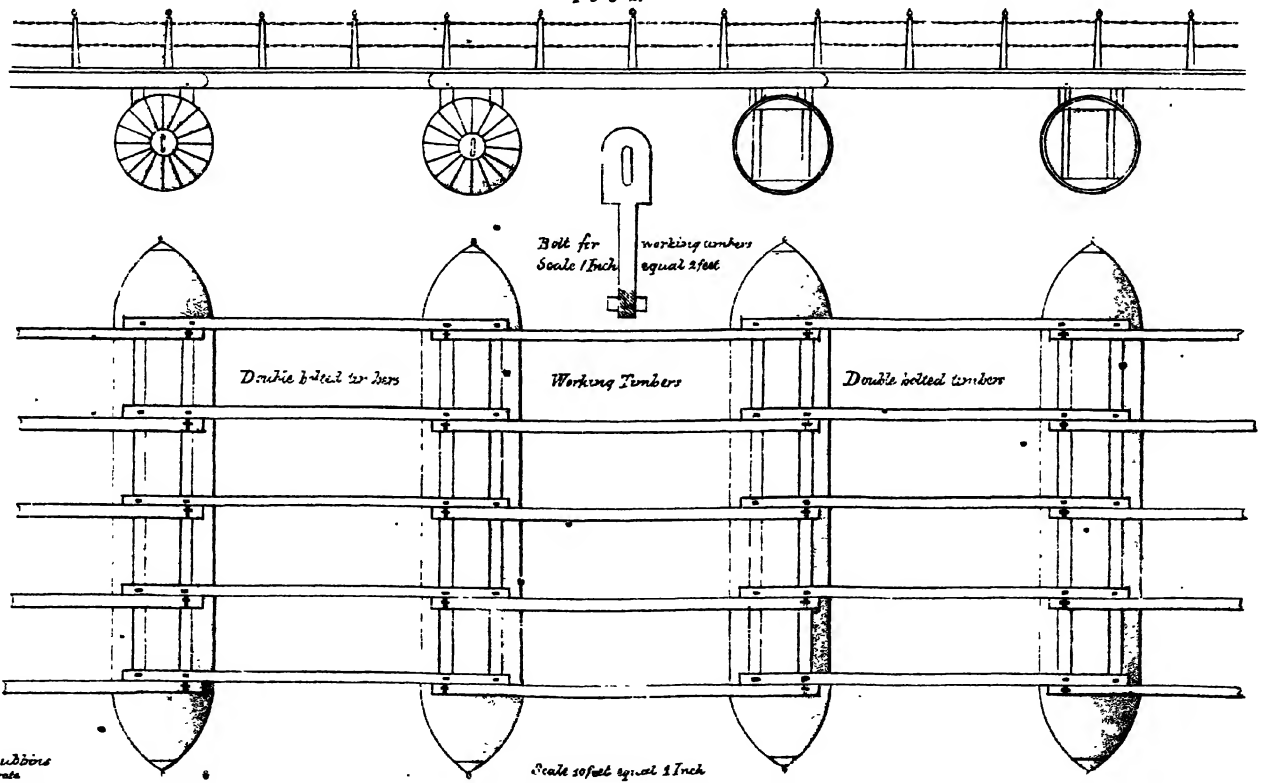
I have the honor to acknowledge your letter No. 2871, dated the 14th instant. Having previously been made aware of His Honor's wish for the preparation of a memorandum upon the comparative advantages of a floating bridge constructed as at Dehlie of wooden boats, and of one supported by iron pontoons as at Agra, the subject has engaged my attention for some time past. I beg now to submit the result of my enquiry for the information of Government.

* *Vide* Page 61 and 64.

† *Vide* Appendix No. I.

DESIGN for a PONTOON BRIDGE

1852.



Signed W. R. Gubbins
Magistrate

Secession Copper Press.

2.—The subject naturally divides itself into branches, viz.

I.—Which of the two bridges proves itself to be the best thoroughfare, and least liable to interruption?

II.—Which of the two bridge proves itself most on the score of economy?

3.—This latter question again embraces two distinct points of enquiry, viz.

I.—Which of the two bridges as now constructed is the cheapest?

II.—Which of the two would be the cheapest, if either bridge were reconstructed with such improvements as experience has been found to recommend?

4.—*Firstly*, which is the best thoroughfare? Upon this point a very strong opinion has been recorded by the Committee which sat in 1848 in the concluding paragraph of their report,* in which they have stated that "there is no floating bridge in the country which can be compared to the Agra Bridge for the ease and rapidity with which the passage can be made." I incline to agree with the Committee in this opinion, but it must be qualified by the remark that there exists no bridge in the country constructed altogether of Government boats, or in other words of boats of one uniform size. But, on the contrary, as the largest number of Government built boats in any bridge does not amount to one-third of the whole,† so boats of different size and tonnage are necessarily hired and moored together, causing irregularities or ascent and descent in the roadway, which would not be were the boats all of one size. I cannot discover any peculiar advantage necessarily attaching to the pontoon construction, as respects ease and facility of passage, superior to what is attainable with boats.

5.—Viewing the Pontoon Bridge indeed in its present construction and condition, I think a Bridge of Boats has the advantage in respect to rigidity of roadway, which of course is a main point in facilitating passage. In this respect the remarks contained in paragraphs 8 and 12 of the Committee's report are no longer applicable. Each pontoon now sinks as a weight passes over it, almost independently of its neighbour, besides having a rolling motion, the two together causing, in my opinion, more undulation than there is in a Bridge of Boats. It will be seen in paragraph 27 of this report, that it is proposed to remedy the defect of the pontoon's rolling by an improved roadway construction; by aid of which, it will, I think, be altogether obviated; leaving than the inequality of roadway caused only by the depression of the pontoon in the water, to be compared with that arising from the oscillation of the two gunwales of a boat. This comparison belongs to the third division of this enquiry, and will be found in a succeeding paragraph, (*vide* paragraph 28.)

6.—But the more important question involved in this branch of the subject is, which form of construction best secures the passage from interruption caused by the bridge being carried away? In this important point of comparison, the experience of the past four years, 1848 to 1851, exhibits little difference between the Dehlie and Agra Bridges. Mr. A. A. Roberts, Magistrate of Dehlie, informs me (in paragraph 7 of his letter No. 116, dated the 1st instant,) that during the four years, 1848 to 1851 inclusive, the passage across the bridge has been only once interrupted, and that was for four days, from the 16th to the 19th February 1851, owing to a sudden rise in the river. I am told that the bridge did not give way, but that several boats had been taken out of it for the sake of economy, the season not being one when much rain is expected; that the river rose suddenly, and access could not be had to the bridge.

* *Vide* Page 64.

† Meaning of course the average number required throughout the twelve months.

7.—On the other hand the annexed Memorandum F., by Mr. A. F. Mackenzie, (Bridge Engineer at Agra,) shows that during the same period the passage over the Pontoon Bridge was interrupted once only in 1849 for three days, when a part of it was carried away by a number of heavily laden boats running foul of it. Both bridges have been kept up throughout the twelve months of the year. The Pontoon Bridge has been carried away once in four years: the Bridge of Boats at Dehlie not at all; if Mr. Roberts is correctly informed as to the cause of the interruption in February 1851, and indeed the season of year at which it occurred, appears sufficiently to confirm the account which has been given to him respecting it.

8.—But notwithstanding this apparent disadvantage in the experience of the past four years, I think the question must be decided in favor of the Pontoon Bridge, because obviously—

First, the pontoons offer so much less resistance to the stream from their shape and size than boats do.

Secondly, so much fewer moorings are needed for a Pontoon Bridge, thereby greatly diminishing the difficulty of getting rid of boats or rafts running foul of it, and which in several instances at Agra, have been carried off by the stream under the Pontoon Bridge.

Thirdly, the pontoons admit more easily and safely of being moored by chain cables, whereby security is much improved, and

Fourthly, they are much more secure than boats against the weather, neither admitting rain nor offering so much resistance to the wind. But further, the current of the river, in freshes at Agra, must necessarily be much stronger than at Dehlie, the stream being here compressed into a channel of less than half the width of that left between the two extremities of the new causeways at Dehlie. The Jumna, while I am writing is at high flood, but does not measure at the bridge more than 1,200 feet in width. At Dehlie, again, where of course there is less water, the river between the east and west causeways, is spanned by a bridge composed of 107 boats, and about 90 platforms, which cannot occupy a less width than 2,700 feet. The current has been running here at 7½ miles an hour. At Dehlie, with a double width of channel, besides a bridge of 7 arches, adjoining on the west, and with the relief afforded by the extensive overflow of the country along the eastern bank, the force of the current must be much less. The powers of resistance, which have successfully opposed, *unequal* forces, cannot of course be considered *equal*.

9.—The appended Memorandum E., by Mr. A. F. Mackenzie, exhibits the system of mooring at present in use for the pontoons, viz., one chain cable to every fourth pontoon; the greater number of which were obtained only last year. In paragraph 8 of his letter, which I have already referred to, Mr. Roberts describes the system of mooring pursued at Dehlie, thus—

"Large stones are deposited in the stream about 100 yards above the boats, and "there is at least one such stone or anchor for each boat. Two cables of *moonj*, "each weighing four maunds, and one cable of two maunds, are attached to this "anchor, and made fast to the prow of the boat. During the rains an additional "cable of six maunds is given to every three boats. Several boats at either end of "the bridge have a long cable running from their bows, which cable is made fast "at some distance beyond the bank, a little above the bridge; and there are two "iron cables which run the entire length of the bridge through the bows of the "boats. The boats are further kept together by *moonj* ropes fastened to each other's "bows, and sterns also. The iron cables I consider a great security in the rains."

On a comparison of the two systems thus described, it is, I think, impossible to avoid the conviction of the great superiority of chain cable moorings over *moony* ropes,—and the enquiry why the Dehlie Bridge of Boats is not supplied with the former. The change would, I think, be advantageous, but it has not yet been tried, and Mr. A. F. Mackenzie thinks* would be attended with some risk.

10.—I proceed to the second branch of enquiry, viz., the relative cost of each bridge, considered firstly, in reference to its construction. In order to make a just comparison we must consider.

I.—THE ORIGINAL COST OF CONSTRUCTION.

II.—THE DURABILITY OF EACH.

III.—THE COST OF YEARLY MAINTENANCE.

And, first, I will examine these particulars in respect to

THE AGRA PONTOON BRIDGE.

I.—*Its original cost of construction.*

11.—This has been shown by paragraph 27 of the Committee's report to be Rs. 1,500 for each pontoon, complete with roadway. The annexed Memorandum A., by Mr. Mackenzie, shews the average cost of each iron pontoon with proportion of chain mooring, to be Rs. 1,065, and of each piece of roadway attached to the pontoon, to be Rs. 549. The durability and repair expenses of these being very different, it will be necessary to consider them separately.

II.—*Durability.*

12.—*Of Pontoon.*—Our experience is not sufficient yet, to enable any correct conclusion to be arrived at, respecting the durability of so durable a machine as the pontoon. Mr. Mackenzie, in the annexed interesting Memorandum C., estimates the age of a pontoon at fifty years. Although the assumption of the duration of any perishable engine of this kind at half a century appears at first extravagant, yet considering that I admit a wooden boat to last twenty years with proper repair, and having nothing to impugn Mr. Mackenzie's data, I have thought it best to adopt his estimate and assume the pontoon to last fifty years. The chain cable will not probably last more than twenty years, but the cost of the one in use forms so small a fraction of that of each pontoon, that a separate calculation for it is unnecessary. After fifty years, Mr. Mackenzie estimate the value of each pontoon at 200 rupees, but I would not assume it at a higher rate than Rs. 100.

13.—*Of Roadway.*—In the annexed Memorandum D., the durability of the present Roadway is estimated at seven years; and its value when condemned, at Rs. 6,000, or nearly one-sixth of its original cost. I have adopted this estimate, reducing the estimated value of the condemned roadway to one-eighth of its original cost. This is the weak point of the Agra Pontoon Bridge. Its construction is defective; the scantling of the beams insufficient, and the deal timber unfitted to the use to which it has been applied. These causes have operated to render necessary a large establishment of workmen, and expenditure of material in repairs, and have caused the roadway to sustain so much injury from wear and tear as to render its renewal indispensable before it will be seven years old. Added to this, the timber was originally procured at high rates, which has raised the cost of the roadway unduly as a standard of future comparison. In the subsequent calculation, based upon the present construction of the Pontoon Bridge, it will be seen how severely the heavy cost and short duration of the roadway tells against it.

* *Vide* Memorandum H., Appendix III.

III.—*Cost of Yearly Maintenance.*

14.—The total charges for the past four years are detailed in annexed Memorandum B. It is evident that the last three details, viz., ghauts, toll houses, and a new road, must not be included in the "cost of yearly maintenance," being more or less common to all floating bridges, and varying not with the different construction of each bridge, but with the character of the river banks. For the same reason that portion of the establishment, which is employed in the collection of tolls, must be excluded. Deducting then the toll collection establishment, the average yearly charge for the establishment employed in the repair and maintenance of the Agra Pontoon Bridge is Rs. 5,604.

15.—Under the head of materials appears a charge of Rs. 13,159-10-3, to which must be added value of materials expended from the bridge godowns, viz., Rs. 3,102, total of the two, Rs. 16,261. It appearing however that more than a fourth of this expenditure was incurred in permanent additions to the bridge, cables, chains, lamps, &c. &c., I have caused it to be distinguished in Memorandum B. into two classes, viz., charges for permanent improvements and charges for repairs.

The former, amounting to Rs. 4,616, have been added to the original cost of the bridge, as shown in Memorandum A., leaving the net charge for repairs in four years Rs. 11,645, viz., *Pontoons* 600, *Roadway* 11,045, yielding a yearly average of

Pontoon,-- -- -- -- --Rs. 150 | *Roadway*, -- -- -- -- Rs. 2,761

16.—The account for the Agra Pontoon Bridge, then, as now constructed, may be summed up as follows:—

	Rs. A. P.	Rs. A. P.	Rs. A. P.
Pontoons.			
1*st.*—Original cost of a Pontoon, with proportion of chain mooring, *vide* paragraph 11, --	1,066 0 0		
Deduct its probable value when condemned, -- -- -- -- -- --	100 0 0		
Net cost, -- --	966 0 0		
Divided by 50 years gives cost for one year, -- --		19 6 0	
2*nd.*—Cost of materials for repair, *vide* paragraph 15, Rs. 150, divided over 70 pontoons, gives -- -- -- -- -- -- -- --		2 2 0	
			21 8 0
Roadway.			
1*st.*—Original cost of one piece of roadway, *vide* paragraph 11, -- -- -- -- --	550 0 0		
Deduct its probable value when condemned, $\frac{1}{8}$, say -- -- -- --	70 0 0		
Net cost, -- --	480 0 0		
Divided by seven years' probable duration, gives cost for one year,-- -- -- -- --		68 9 0	
2*nd.*—Cost of materials for repair, *vide* paragraph 15, Rs. 2,761, divided over 66 pieces, gives -- --		41 13 0	
			110 6 0
Establishment for Repairs.			
Average annual charge, *vide* paragraph 14, Rs. 5,604, divided by 70 pontoons, gives for each -- -- -- -- --			80 0 0
Total charge for one pontoon and piece of roadway for one year, -- -- -- -- -- -- -- -- --			211 14 0

17.—I proceed to a like examination of the cost particulars of

THE DEHLIE BOAT BRIDGE.

I.—*Its original cost of Construction.*

It appears from paragraph 5 of Mr. A. A. Roberts' letter, No. 116, that the 19 boats built near the hills in 1843-44, at a cost of about Rs. 450 each, are still in good and serviceable order, and may be expected to last for seven or eight years more, at the least. The roadway deck to these boats is a separate charge, amounting to about the same as the platform, viz. Rs. 144.* The cost, therefore, for a good boat, with a three inch planked roadway deck, and a like platform attached, is Rs. 450 + 144 + 144 = Rs. 738.

II.—*Durability.*

18.—I subjoin the opinion with which I am favored by Mr. Roberts in reference to the Government-made boats in use in the Dehlie Bridge, and by Mr. D'Gruyther, the Deputy Magistrate of Furruckabad, in respect to nineteen boats which were constructed at that station in 1844-45 of the very best materials.

Mr. Roberts says:—"The remaining eighteen boats were built in 1843 and 1844. All of these boats are in good and serviceable order, and may be expected to last for seven or eight years more at the least. A good wooden boat should last full twenty years, with possibly slight repairs after ten years' use. The natives use their boats much longer, and I dare say many of ours will not be condemned even at the end of twenty years, but this is a question to be determined by time alon The platforms are calculated to be as durable as the boats."

Mr. D'Gruyther observes:—"The number of boats, that were built here for the bridge of boats in 1844-45, is nineteen. All the boats are still in use, and it is expected they will last for the next four or five years."

19.—My own enquiries lead me, after duly weighing the foregoing opinions, to conclude that a good boat will last ten years with very trifling repairs: and, if then thoroughly repaired at an outlay of two-fifths of the original cost, it will last for ten years longer. Considering that the planking and beaming of the platform is particularly stout and strong, the outlay after ten years, for renewing may, including both boat and platform, be taken at one-third; and the value of both, after twenty years' use, be assumed at one-tenth of the original cost.

III.—*Cost of yearly maintenance.*

20.—In examining this point, I must refer to the annexed table,† furnished to me by Mr. Roberts, detailing the several charges incurred in the two past years, 1850 and 1851. An examination of these details has enabled me to distinguish the charges which appertain to the head under examination from those which should be excluded from it. The result is exhibited in the following Memorandum showing the total chargeable expenditure to average Rs. 8,525-7-1½.

**Vide* Paragraph 42 of Committee's Report.

† Appendix No. II.

Memorandum of the average Disbursements on account of the Bridge of Boats at Dehlie on account of the two years, 1850 and 1851.

Disbursements not chargeable to the cost of yearly maintenance.				Disbursements chargeable to the cost of yearly maintenance.			
Number.	Item of Expenditure.	Rs. A. P.		Number.	Item of Expenditure.	Rs. A. P.	
1	Establishment for collecting Tolls, ...	2400 0 0		2	Establishment, including 12 mullahs for maintaining and repairing bridge, ...	1833 0 0	
5	Hire of boats, ...5035 15 1			3	Extra boatmen, ...	395 10 9	
	Deduct wages of 23 mullahs, who must be entertained if the boats were the property of Government, charged per contra, ...1104 0 0			4	Carpenters, &c., casual, ...	532 4 5½	
		3951 15 1		5	Wages of 23 mullahs required to make up the complement of 35 mullahs for 69 boats, if, instead of being hired they were the property of Government at 48 Rs. each per annum, ...	1104 0 0	
6	Wood for platforms deducted being a permanent charge of construction, ...	1072 0 0		8	Petty repairs, ...	43 6 10½	
7	For decking boats ditto ditto, ...	1031 10 0		9&14	Mooni cables and anchors, ...	3709 1 8½	
12	Grass, &c., and labor in constructing approaches, ...	912 2 4½		10	Caulking boats, ...	25 13 9	
				11	Grass for bridge roadway, ...	203 8 0	
				12&15	Iron nails, &c., and miscellaneous charge,	618 10 1	
	Total, ...	9367 11 5½			Total, ...	8525 7 1½	

To this, however, must be added the subjoined charges, which would have been incurred if the Dehlie bridge had been constructed altogether of Government boats:

Add to No. 2 "Establishment" to double the present charge for carpenters, -- -- -- -- -- -- -- -- Rs. 135 0 0

3 "Extra boatmen" to complete the complement to one boatman for each of the 69 boats during the four rainy months, -- -- -- -- -- -- Rs. 148 5 9

4 for "Casual Carpenters, &c." one-fourth more additional, -- -- -- -- -- -- -- -- Rs. 133 0 0

8 to double the present charges for "Petty Repairs," Rs. 43 0 0

10 to treble the charge for "Caulking," -- -- -- Rs. 51 11 6

11 to make up the full price of the "Grass, &c." used for the bridge road; this item being undercharged as explained by Mr. Roberts, -- -- Rs. 263 8 0

13 and 15 the probable additional charge for "Iron Nails" and "Miscellaneous Charges," on account of 47 other Government boats, -- Rs. 188 0 0

Total, Rs. 962 9 3

yielding a sum total of Rs. 9,488-0-4½, which divided over 69 boats, (the average number employed) makes the amount yearly chargeable to each boat to be Rs. 137-8-0.

21.—Accordingly, the result of the examination into the cost of the Dehlie boat bridge may be summed up as follows:—

Boats and attached platforms.

1.—Original cost of a boat decked with a 3″ roadway, and a 3″ plank platform attached, *(vide paragraph 17,)* -- -- -- Rs. 738 0 0

2.—Add one-third for estimated cost of thorough renewal after 10 years, *(vide paragraph 19,)* -- -- Rs. 246 0 0

Total cost for 20 years, 984 0 0

Deduct probable value after 20 years, *(vide paragraph 19,)* = $\frac{1}{10}$th = 98 0 0

Net Rs. 886 0 0

Divided by 20 years gives cost for one year, -- -- -- -- -- -- 44 4 0

Cost of establishment, materials, &c., for maintenance and repairs, *(vide paragraph 20,)* -- -- -- -- -- -- -- -- -- -- --137 8 0

Total charge for one boat, and price of roadway for one year, -- --181 12 0

22.—But the greater breadth of the boat, which is shown in paragraph 42 of the Committee's report, to bear the proportion to an iron pontoon of 3 to 2, requires the further adjustment of the comparison by multiplying the annual cost of the pontoon, viz., Rs. 211-14-0, *(vide paragraph 16,)* by 3, and that of the boat just deduced, viz., Rs. 181-12-0 by 2. The final comparison therefore stands thus :—

Pontoons, --	211 : 14	× 3	=	Rs. 635 : 10
Boats, -- --	181 : 12	× 2	=	Rs. 363 : 8

and shows the pontoon bridge, as now constructed and maintained, to be nearly twice as expensive as a bridge of boats.

23.—I proceed to the last division of my subject, to enquire which bridge might be made the cheapest, by the adoption of those improvements in construction which experience recommends. As regards the Dehlie boat bridge, the only improvement that suggests itself to me is, to exchange the present *moonj* rope moorings for chain cables. The yearly saving that would result from this charge would be very large, amounting to Rs. 48-12-0 per boat per annum, as thus shown.

Present average yearly charge for moonj moorings for 69 boats, *(vide memorandum attached to paragraph 20,)*--Rs.	3,709	0	0
Giving each boat, -- -- --	53	12	0
Cost of an English chain cable, -- -- -- -- -- --	100	0	0
Divided again by 20 years, the probable duration, gives for each year, --	5	0	0
Showing a yearly difference in favor of the chain cable per boat, of -- Rs.	48	12	0

24.—Some reduction might also be effected in the price of the platforms and deck roadways, if they were constructed, as well as the boats, in the neighbourhood of the hills.

This saving may be estimated at say 10 per cent. reducing the cost of one boat, complete with platform, &c., to Rs. 710; thus 450 + 130 + 130 = 710.

25.—In constructing a new Pontoon Bridge on the other hand, an extraordinary saving would undoubtedly be obtained.

1*st.*—By a better mode of construction, whereby material and establishment would be saved, and the duration of the materials greatly prolonged; and

2*ndly.*—By procuring the sheet iron, and the timber from those markets where they are cheapest, whereby a great reduction would be effected upon the prices before paid. It must not be forgotten that the present Agra Pontoon Bridge is the first of its kind constructed, and is therefore an experiment. Although, therefore, the success of the experiment reflects great credit on those who planned and executed it, yet in every succeeding construction, improvement may naturally be expected to result from the experience gained.

26.—In the Appendix, Memorandum G., Mr. Mackenzie estimates the probable cost of Pontoon at Rs. 900, supposing the material to be purchased in Calcutta, and I do not think the estimate unfair. It applies to the present form or size of Pontoon in which no change seems absolutely required. Some increase in the size would however be probably found useful; and before commencing upon any new bridge, the best advice should be taken upon this subject.

27.—But the plan of the roadway must be greatly changed and simplified. The new proposed mode of construction is detailed in the same Memorandum G., and explained

by accompanying Plan and Section. The improved strength and simplicity of the new model will readily be admitted. In lieu of the saddles and their riding pieces, which have been found liable to shift and give way, two longitudinal beams are substituted. In lieu of three weak main timbers, each composed of three pieces, (*no single piece having a greater thickness than 3″), the new model provides for five main timbers each 12″ by 9″, which renders the intermediate framing quite unnecessary. In lieu of these main timbers being only 15½ feet long, and being in consequence made to rest on the *inner* edge of either pontoon, thereby causing a rolling motion, the new beams will be 22 feet long, and will stretch to the outer edge of both pontoons, and being firmly bolted to each, all rolling motion will be prevented. The planking, in lieu of being partly saul and partly deal, and varying from 3 to 2 inches in thickness, will be all saul and 3½ inches thick.

28.—The rolling motion of the pontoon being thus remedied, the only cause of unevenness in the plane of the roadway will be found in the dip or immersion of each pontoon bodily into the water by the pressure of a superincumbent weight. I cannot precisely say what comparison this wavy motion will bear to the oscillation of the roadway of a bridge of boats occasioned by the dip of one gunwale of a boat, and the elevation of the other: but, from the experiments which have been made, I apprehend that there will not be much difference between the two. In Mr. A. F. Mackenzie's experience, when a hackery or other weight keeps upon the proper roadway, *i. e.*, near the centre, the pontoon has never been depressed more than 18 inches, although when the weight has been forced near to the edge of the roadway, the near extremity of the pontoon has been immersed as much as two feet. The extreme dip of a boat's side, again, I am informed by Mr. A. A. Roberts, does not exceed nine inches, giving a corresponding elevation of nine inches for the opposite gunwale, equal to a total oscillation of eighteen inches. By lengthening the beams of the platforms from 20 to 21 feet, and relieving the gunwales of the boats from their pressure, and placing the first supports two feet or more from the gunwale, (*i. e.*, two feet nearer the boat's centre, or the axis of oscillation,) the latter would be considerably diminished, and much improvement in the evenness of the roadway effected.

29.—In comparing the timber required for the old and new constructions, a very great saving of material is however effected, by avoiding the almost daily repairs of the slight timbers now needed. On the other hand, I see no reason why a roadway, so constructed, should not endure as long as that of a bridge of boats, and I would therefore apply the same calculation to both, viz., a duration of 20 years, allowing for a thorough repair after 10 years, at an outlay of one-third of the original cost.

30.—But the improved construction will also admit of a considerable reduction in establishment; the present regular workmen being chiefly employed in repairing the constant injuries to the roadway. The subjoined Memorandum exhibits the saving which may be anticipated:—

PRESENT.	Rs. A. P.		
1 Superintendent's Salary, ...	150 0 0		
Commission, ...	82 0 0		
		232 0 0	
2 Chowdries and 16 mullahs, ...		77 0 0	
9 Blacksmiths, ...		65 0 0	
10 Carpenters, ...		60 0 0	
Chupprassees, chowkeedars, &c., ...		33 0 0	
Per mensem, ...		...	467 0 0
Per annum, ...		...	5601 0 0

PROPOSED.	Rs. A. P.		
1 Superintendent, ...	150 0 0		
1 Chowdree and 16 mullahs, ...	71 0 0		
Blacksmiths, ...	40 0 0		
Carpenters, ...	40 0 0		
Chupprassees, &c.	16 0 0		
Per mensem,... ...			317 0 0
Per annum, ...			3804 0 0
Divided by 65, gives per pontoon,			58 8 0

* *Vide* paragraph 26, Committee's Report.

31.—An estimate of the cost of the new roadway is given in Memorandum G., amounting to Rs. 430, in which I have made a correction in respect to the price of timber, after consulting the Magistrates of Dehlie and Saharunpoor: by which the cost of roadway is encreased 50 Rs., as exhibited in the marginal memorandum.* The prices stated are those at which contractors will engage to deliver squared beams and planks at Dehlie.

		Rs.	Rs.A.P.
* 10	Saul timbers, ...	at 14	140 0 0
36	Saul planks.	at 5	180 0 0
10	Bolts, ...	at 2	20 0 0
10	Ditto, ...	at 2-8	25 0 0
45	Ditto, ...	at 1	45 0 0
3	Sheets Iron for bands, ...	at 6	18 0 0
	Carpenter's labor, ...		52 0 0
	Total, Rs.		480 0 0

32.—The enquiry therefore exhibits the result subjoined:—

Estimate of yearly cost of one Pontoon, complete with Roadway on improved construction.

No.	Detail.	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.
1.	*Pontoon.*—Cost of one pontoon, -- -- --	900	0	0						
	Deduct probable value when condemned,-- --	100	0	0						
	Net cost,-- -- -- -- --	800	0	0						
	Net cost to be divided over 50 years, giving cost for one year, -- -- -- -- -- --	--	--	--	16	0	0			
	Cost of one chain cable one hundred feet long,--	100	0	0						
	Divided by 4, one cable being allowed to 4 pontoons, -- -- -- -- -- -- -- --	25	0	0						
	Divided again by 20 years' estimated term of duration, gives -- -- -- -- -- --	--	--	--	1	4	0			
	Cost of material for repairing pontoons, -- --	150	0	0						
	Divided over 70 pontoons, give-- -- -- --	--	--	--	2	2	0			
								19	6	0
2.	*Roadway.*—Cost of one piece of roadway, --	480	0	0						
	Add $\frac{1}{3}$ for renewal after 10 years, -- -- --	160	0	0						
	Total cost for 20 years, -- --	640	0	0						
	Deduct probable value after 20 years, viz. $\frac{1}{10}$th,--	64	0	0						
	Net, -- -- --	576	0	0						
	Divided by 20 years, gives cost for one year, --	--	--	--	28	13	0			
	Cost of materials for repair has been for the present bridge, -- -- -- -- -- --	2761	0	0						
	Deduct for improved construction one-half, --	1380	8	0						
	Leaving estimated future cost, -- -- -- --	1380	8	0						
	Divided over 66 pieces, gives for each -- --	--	--	--	20	14	0			
								49	11	0
3.	*Establishment.*—Establishment for repairs and maintenance, -- -- -- -- -- -- -- -- -- -- -- --							58	8	0
							Total, Rs.	127	9	0

Estimate of yearly cost of one Boat, complete with Roadway, built near the Hills and moored as at present with moonj ropes.

No.	Detail.	Rs. A. P.	Rs. A. P.	Rs. A. P.
1.	*Boats.*—Cost of Boat with roadway, deck and platform,	710 0 0		
	Add $\frac{1}{5}$ for renewal after 10 years,	236 10 0		
	Total cost for 20 years,	946 10 0		
	Deduct, probable value after 20 years, viz. $\frac{1}{10}$th,	94 10 0		
	Leaving net cost for 20 years,	852 0 0		
	Giving cost for one year,		42 9 0	
2.	*Repairs and Establishment.*—Cost of Establishment, materials, &c., for maintenance and repairs, *(vide paragraph 20,)*		137 8 0	
	Total,			180 1 0

And the comparison of the improved Pontoon Bridge and of the Boat Bridge, moored as at present with *moonj* rope cables, stands thus :

Pontoons,	127 : 9 × 3 =	Rs. 382 : 11
Boats,	180 : 1 × 2 =	„ 360 : 2

or, for a river of the same width as the Jumna at Agra,

Pontoons,	127 : 9 × 65 =	Rs. 8281 : 9
Boats,	180 : 1 × 43 =	„ 7742 : 11
Difference per annum in favor of boats,		Rs. 528 : 14

33.—But, by making the proposed substitution of chain cable for *moonj* rope moorings, the result is much more favorable to the boat bridge as shown in the following Memorandum, the yearly cost per boat being reduced (by subtraction of Rs. 48-12-0, *see paragraph 23*) to Rs. 131-5-0.

Pontoons,	127 : 9 × 65 =	Rs. 8281 : 9
Boats,	131 : 5 × 43 =	„ 5646 : 7
Difference in favor of the boats per annum,		Rs. 2635 : 2

34.—In the foregoing calculation no account, it will be observed, has been taken of the interest on the capital expended, which is nevertheless an essential element in a computation of this nature, if real accuracy be desired. The balance of interest is of course from the larger original outlay in construction, considerably against the Pontoon Bridge.

35.—I conclude therefore that as respects,—

First.—Goodness of thoroughfare, and use of passage, both forms of construction are equal.

Secondly.—Liability to interruption, the iron pontoon form is superior, and

Thirdly.—Economy both as regards present construction, and future possible improvement, the bridge of boats is the least expensive.

36.—In prosecuting this enquiry, I have received much valuable aid from Mr. A. F. Mackenzie, the Pontoon Bridge Engineer, whose intelligence, experience, and practical skill as a mechanic might be made more extensively useful than it is at present in the superintendence of the single Bridge at Agra.

APPENDIX No. I.

Rough Statement of Receipts and Disbursements at the Dehlie and Agra Bridges, during the years from 1848 to 1851, both inclusive.

Years.	Receipts.			Disbursements.						Net Receipts.
	Collection from traffic and passengers.	Miscellaneous.	Total.	Establishment for Collections.	Fixed Establishment for repairs.	Extra hired workmen for repairs.	Material for repairs.	Construction or repairs of approaches to Bridge.	Total.	
Dehlie Bridge of Boats.										
1848, ...	38636 5 5	163 13 0	38800 2 5	1944 0 0	3598 1 11	1053 9 11	5521 15 6	1118 12 8	16236 8 0	20563 10 5
1849, ...	33541 1 10	0 0 0	33541 1 10	2028 0 0	3431 7 7	1341 9 8	4964 1 3	495 11 9	17260 14 3	10280 3 7
1850, ...	40274 8 8	0 0 0	40274 8 8	2088 0 0	5788 10 5	1332 5 6	4819 4 4	309 0 2	14337 4 5	25937 4 3
1851, ...	40757 11 8	0 0 0	40757 11 8	2295 8 0	3605 11 9	2260 4 4	9172 5 5	262 9 2	22396 6 8	18361 5 0
Total,..	153209 11 7	163 13 0	153373 8 7	8155 8 0	31423 15 8	5987 13 5	24477 10 6	2186 1 9	72231 1 4	81142 7 3
Agra Pontoon Bridge.										
1848, ...	31919 5 11	2658 8 4	34577 14 3	3523 4 6	4656 7 9	745 4 8	7828 10 22	6714 4 1	23467 15 23	11109 15 0
1849, ...	30264 6 11	458 0 0	30722 6 11	3157 6 9	3605 14 0	200 0 0	777 12 4	111 8 0	7942 9 1	22779 13 10
1850, ...	36013 4 3	12667 10 8	48680 14 11	3414 0 7	3690 0 0	0 0 0	1509 4 0	1572 8 0	10101 12 7	38489 2 4
1851, ...	31272 6 0	0 0 0	31272 6 0	3164 7 5	3096 0 0	0 0 0	1200 0 0	1009 8 0	9069 15 5	22202 6 7
Total, ..	129469 7 1	15784 3 0	145253 10 1	13259 3 3	15744 5 9	945 4 8	11315 10 63	9407 12 1	50672 4 34	94581 5 9

APPENDIX No. II.

Annual Charges, for 1850 and 1851 of the Bridge at Dehlie.

No.	Purposes.	1850.	1851.
1	Establishment for collecting tolls and managing bridge,	2400 0 0	2400 0 0
2	Ditto for maintaining bridge, viz., boatmen, carpenters and others,	1833 0 0	1833 0 0
3	Extra boatmen during the rains,	455 10 9	335 9 9
4	Carpenters and workmen, casual,	316 12 5	747 12 6
5	Hire of boats,	3643 10 5	6468 3 9
6	Wood for platforms,	0 0 0	2144 0 0
7	Ditto for decking boats,	0 0 0	2063 4 0
8	Ditto for petty repairs,	0 0 0	86 13 9
9	*Moonj* rope for cables,	3785 4 6	3316 4 0
10	Dhak roots for caulking boats,	23 13 0	27 14 6
11	Grass for roadway of the bridge,	274 0 0	253 0 0
12	Grass, Jhao, &c., including labor for making approaches to bridge and keeping road over the sand in repair,	962 7 2	861 13 7
13	Iron nails, &c.,	68 4 11	305 12 8
14	Carriage of large stones for anchors,	162 4 11	154 6 0
15	Miscellaneous, stationery, &c.,	412 10 7	450 8 1
	Total, Company's Rupees	14337 14 8	21448 6 7

A. A. ROBERTS.

Dehlie, *31st May 1852.*

APPENDIX No. III.

Memoranda by Mr. A. F. Mackenzie, Superintendent of the Pontoon Bridge on the Jumna, at Agra.

MEMORANDUM A.

	Pontoons.	*Roadway.*	*Total.*
	Rs.	Rs.	Rs.
The cost of the 70 Pontoons and Roadway of this bridge is stated in the Committee's Report for 1847-48, amounted to -- -- -- -- -- -- -- --	75933	35854	111787
Miscellaneous items added by Committee, -- -- --	5500	3437	8937
Total, --	81433	39291	120724
Deduct (proportionally) " Materials in hand," -- --	8000	4336	12336
Cost in 1848, -- -- -- -- -- -- -- -- -- --	73433	34955	108388
Add subsequent expenditure by permanent improvements, viz., pontoons, chain cables, &c., -- -- -- Roadway lamps, iron bands, &c., -- -- -- -- --	1155	3461	4616
Total cost complete, Rs.	74588	38416	113004
Or per each Pontoon with Roadway, (Total divided by 70,)	1065	549	1614

MEMORANDUM B.

Since the completion of the bridge there has been expended a total of Company's Rupees 5,21,273, as follows :

Year.	Establishment.	Materials.	Ghat.	Toll Houses.	New Road.	Total.
In 1848,	8925 0 11	6890 9 11	6691 3 4	508 0 0	453 0 0	23467 14 2
„ 1849,	6853 4 9	977 12 4	111 8 0	0 0 0	0 0 0	7942 9 1
„ 1850,	7110 0 7	3081 12 0	0 0 0	0 0 0	0 0 0	10191 12 7
„ 1851,	6860 7 5	2209 8 0	0 0 0	0 0 0	0 0 0	9069 15 5
Total,	29748 13 8	*13159 10 3	6802 11 4	508 0 0	453 0 0	50672 3 3

* Besides the "Materials" as above,=Co.'s Rs. 13159 0 0

There have been expended " Materials from Godowns," valuing -- 3102 0 0

Total expenditure, Rs. 16261 0 0

Distributed as follows :

Total Amount.	*Permanent Improvement.*		*Repairs.*	
	Pontoons.	Roadway.	Pontoons.	Roadway.
Rs. 10298 0 0	105 0 0	0 0 0	250 0 0	9943 0 0
3102 0 0	1050 0 0	600 0 0	350 0 0	1102 0 0
2861 0 0	0 0 0	2861 0 0	0 0 0	0 0 0
Rs. 16261 0 0	1155 0 0	3461 0 0	600 0 0	11045 0 0

There has therefore been expended during four years,

For Repairs, --	On Pontoons, -- --	Rs.	600
	On Roadways, -- --	Rs.	11,045
	Total, Co.'s	Rs.	11,645
	or for one year, Co.'s	Rs.	2,911

It will be observed that in 1848 the expenditure for material is large. Such is not likely to occur again until the roadway requires an entire renewal. Much of the material was expended in improvements of a permanent nature, such as anchor, chains, lamps, &c.

The principal expenditure of the above-mentioned years has been mainly caused by an early mistake in the partial use of deal timber instead of saul, (the supply of the latter timber having been deficient,) and some of the planking first employed not proving thick enough.

MEMORANDUM C.

I estimate the durability of the pontoons at fifty years, in consequence of the little injury they have as yet sustained. Some of them have been in the river already six years, and it is from a careful examination of these pontoons I am enabled to form an opinion. In fact, if they be kept properly tarred, I think I have under-valued their durability. With the coal tar alone, however, I have observed damage done by an insect, (which I will presently describe,) and was therefore led to mix some finely powdered arsenic and quicklime. This has had the desired effect; for although a few insects are still to be found, they do no injury. I have also tried galvanism, as recommended by the Committee in their Report, paragraph 20, by attaching to the after end of the pontoon a plate of zinc $8'' \times 8'' \times 1\frac{1}{2}''$ (the pontoon having been previously scrubbed bright all over, and no coating of any kind afterwards applied,) and find corrosion to any extent prevented, small spots only appearing at some 8″ or 10″ apart. I propose zincing at both ends of the pontoon and am inclined to think that by these means the corrosion will be entirely prevented. Some benefit may be derived from coating with coal tar and arsenic all those parts not in contact with the zinc, and this is about to be tried. Each experiment, however, takes a year to show any result. On the galvanized pontoon, I have not discovered a single insect. There does not appear any great difference in the extent of the oxydation, whether the pontoon is afloat or aground.

The pontoons possess one great advantage over boats, viz., should they at any time, from accident or inattention, or even from actual wear, become unsound in those parts now immersed, they can with little trouble or expense be inverted, and in such a case their efficiency will not be at all impaired. This property is not however taken into consideration in the estimate of 50 years.

Their value at that period for old material will depend on the then value of iron. If of the same, or nearly of the same, value as at present, (I should say that as the upper half of the pontoon will be nearly as good as new, it may be taken at Co.'s Rs. 200 each ;—the natives value old iron at a much higher rate than new,) the deterioration of each pontoon per year may be thus reckoned :—

Its original cost without moorings, was -- -- -- --	1,050	0	0
Its value at end of 50 years, -- -- -- -- -- -- --	200	0	0
Its wearing value, -- -- -- -- -- -- -- -- -- --	850	0	0
which divided by 50 gives per year, Co.'s Rs. -- -- -- -- --	17	0	0

The insect before referred to is a kind of worm about $\frac{1}{8}$ of an inch in length and a line in breadth. It has four legs (two on each side) near the head, which is armed with powerful forceps, similar in appearance to that of the black ants. On those pontoons coated with coal tar alone, they formed a sort of capsule of a conical shape, about $\frac{5}{16}$ths of an inch in diameter at the base, and about $\frac{3}{8}$ths of an inch in height. This capsule was generally of a reddish brown color, apparently caused by oxyde of iron. It was invariably found filled with clear water (whether that in the river was so or not) in the centre of which was the insect. Immediately under the capsule, the coal tar was always found removed, and the iron corroded to the depth of about the thickness of a sheet of drawing paper, presenting a beautiful bright surface, and showing distinctly the laminæ of the iron in very fine silky-looking threads. The insect taken from such a capsule was found to be largely impregnated with iron. It does not seem at all probabe that the insect attacks the metal, but as it evidently cuts away the coal tar and exposes the surface of the iron to the action of the water, it seems likely that the insect becomes impregnated with the metal, from the water in which it lives being so. On those pontoons coated with the arseniated coal tar, those insects which are found do not contain iron, and are so scarce that I have had difficulty in procuring a few as specimens. They do not form capsules like the others, but little tubular cases, closed at one end, sufficiently large to admit of free ingress and egress.

MEMORANDUM D.

The wear and tear of the bridge is principally confined to the roadway. From many observations made with reference to its durability, it appears that, if constructed of 3″ planking as at present, it may be taken at seven years without any very material repair. I also find that for any bridge, with the traffic of the one at Agra, planking of a less thickness should on no account be used. The first few pontoons that were constructed had roadway planking of 2″ and $2\frac{1}{2}$″, and it is in these instances, (the decay of the deal timber being also considered) that any large repairs have been required. In case of the roadway being entirely renewed, the old material would not be worth less than Co's Rs. 6,000.

MEMORANDUM E.

There are in the bridge 65 pontoons, moored by 16 English chain cables, each cable capable of bearing a strain of 10 tons. Every fourth pontoon is moored by one of these chains. The anchors are of red sandstone, each about 8 or 10 maunds in weight. These sink each year about $1\frac{1}{2}$ feet deeper in the sand, and the chains have to be lengthened accordingly. We have however plenty of chain for lengthening for some years to come, by which time this sinking will probably cease. Some few of the intermediate pontoons in the main stream have other chains, made up here of English round bar iron in links of two feet in length. This is the description of chain by which the bridge was first moored. It was found however, that as the bridge floated or grounded, these chains were very liable to get twisted and break. Of these chains there now remain in the river 17. There were originally 32, and the cost of each was Rs. 20.

Hence 32 × 20,-- -- -- . -- -- -- -- Co.'s Rs.	640	0	0
The English cable, 400 feet, from Calcutta, cost „	414	0	0
And 1,500 feet purchased at Magazine auction, „	105	0	0
Total cost of permanent moorings,	1159	0	0

The bridge may now be considered permanently moored; the 16 English cables, above-mentioned, being more than sufficient for all ordinary purpose.

A pontoon bridge requires much less mooring than a boat bridge; as the pontoons offer so much less resistance to the stream, both on account of their rounded shape and less width.

I should take this difference in resistance to be as 1 to 4.*

MEMORANDUM F.

The only serious stoppage to the passage over the bridge happened in 1849, when the bridge was partly carried away by a number of heavily laden boats coming foul of it in consequence of a sudden rise in the river. The bridge was stopped for three days. The breaking of a beam or plank seldom interferes with the passage, and then only for an hour or so; if not of immediate importance, such repairs are generally carried on at night. Of course the bridge is again liable to such an accident as that of 1849, but as the moorings are stronger, a like extent of damage is not to be anticipated.

MEMORANDUM G.

The Committee in their Report, paragraph 45, suggest that a new boat-like (or oval) pontoon, might, with advantage, be used instead of the cylindrical one, which they object to, principally from its grounding sooner than the former. This objection is met by the fact that the cylindrical pontoon previous to grounding forms a bed for itself in the sand, at least a foot deep; and its greater facilities for being moved about (by rolling) besides being easier of construction, should, I think, give this form the advantage. (Both forms possess the same facilities for being inverted, see parapraph C.) Should the suggestions of the Committee in their paragraph 34 be adopted, with reference to the purchase of material, there can be no doubt but that a saving of from 10 to 15 per cent. would be effected in the construction of any other pontoon. Their cost would probably be about Co.'s Rs. 900 each.

The accompanying plan, for an improved roadway, has reference to the observations of the Committee in their several paragraphs Nos. 8, 16, 26 and 34, and is intended to possess the following advantages over the present roadway, viz., a rigid roadway, (by which the pontoons are prevented from rolling with little consequent or no strain on the timbers); facility of being taken to pieces without injury; simplicity of construction (all the beams, &c., being alike); saving in iron work, and a much greater durability (from there being less strain, and a greater scantling).

The proposed roadway to consist of 5 main timbers (A.,) 22 feet long, 1 foot deep, by 9″ wide, supported (instead of saddles,) by two other timbers (B.) of the same dimensions, which timbers will be supported by an inside trussing similar to those now in use in the Agra Bridge. The whole of the pontoons to be firmly bolted together in pairs 12 feet apart, as at present, and these pairs connected together with beams so bolted as to admit of play at either end. The planking will consist of 36 planks, each 13 feet long, 1 foot wide and 3½ inches thick (C.) and either secured by iron bands, (D.) bolted alternately at every 2 feet, or each plank bolted down separately. The roadway will be 26 feet wide or two feet wider than the Agra roadway, and this will add greatly to the facilities of passage. It will be advisable that the timber be contracted for, and it should be cut and squared to proper length and

* During the floods of the late rainy season (1852) which have proved unusually high and rapid, one of the chain cable anchor stones which had been deposited in the river bed since July 1851, and must have sunk to a depth of 14 to 20 feet in the sand of the river bed, was swept down from its former position to one underneath the pontoons, and thus during the heaviest flood its force was exerted against instead of in favor of the bridge.

M. R. GUBBINS.

scantling by the contractor, by which means a great saving will be effected in carriage and carpenter's labor, and sound well-seasoned timber will be insured. The probable cost of such a roadway for each pontoon would be—

7	Timbers for road and pontoon,	@	20,			140	0 0
3	Ditto for sundries,	@	20,			60	0 0
36	Saul planks,	@	2,			72	0 0
10	Bolts,	@	2,			20	0 0
10	Ditto,	@	2-8,			25	0 0
45	Ditto,	@	1,			45	0 0
3	Sheets iron for bands,	@	6,			18	0 0
	Carpenter's labor,		say			50	0 0
				Total, Co.'s Rs.	--	430	0 0

or nearly 20 per cent. under that of the Agra roadway, but much will depend on the price of the timber. Should the proposed plans be adopted, there will be a durability nearly treble that of the present roadway. It would require little or no repair for the first 12 or 14 years, and with a thorough repair at the expiration of that period, would last for 6 or 8 years longer.

The establishment necessary for the working and repairs of a bridge of the proposed construction, would be, for working:—

1 mullah to every 4 pontoons, and 1 chowdhree to whole bridge.

The establishment for repairs for the first 7 years,

1 head blacksmith,	@	12	Rs.	32	0 0
4 assistant ditto,	@	5			
1 carpenter,	@	10	Rs.	34	0 0
4 assistant ditto,	@	6			
and for contingencies, *i. e.* jhao, oil, charcoal, &c.,			Rs.	100	0 0
		Per month, Co.'s Rs.		166	0 0

MEMORANDUM H.

My opinion of chain cable moorings for a bridge of boats is, that there would be great risk attending their use, in case of any heavy boat running foul of the bridge.

If a boat were to come against a bridge so moored at a velocity of 5 or 6 miles per hour, it would either sink the boat it ran foul of, or so shatter it that it would not long float. I need hardly say that, if, in a well-constructed bridge of boats, well connected together, one boat were to sink, it would most probably sink its fellows, and so on the whole bridge.

Moonj moorings from their elasticity would considerably break the shock in such a case and save the boat from injury, and if the strain on the bridge were great, it would give way, and but little damage ensue. At all events the probabilities of loss of boats and sinking of the whole bridge would not be so great with moonj as with iron.

A. F. MACKENZIE.

BRIDGE OVER THE RIVER KUNOUT AT SHAHJEHANPORE.

CONSTRUCTED FOR THE RANEE OF POWAINE, UNDER THE SUPERINTENDENCE OF THE DISTRICT ROAD FUND COMMITTEE, ON A DESIGN SUPPLIED BY COLONEL ABBOTT.

From C. ALLEN, Esq., *Officiating Secretary to Government in the N. W. Provinces, Judicial Department, to* H. PIDCOCK, Esq., *Commissioner of the Rohilcund Division, (Government Order, No. 5491 of 1848,) dated Agra, the 11th November 1848.*

SIR,

In reply to your letter of the 1st instant, No. 93, with enclosures, reporting the completion of the bridge over the river Kunout, at Sindhowlee Ghaut, in zillah Shahjehanpore, I am directed to express the gratification of the Honorable the Lieutenant-Governor, on receiving intelligence of the completion of this highly useful and ornamental public work, and to beg that you will communicate to the Ranee of Powaine, the satisfaction which His Honor derived from inspecting it last year in its incomplete estate, and now from receiving intelligence of its being completed in all its parts.

2.—To Mr. C. B. Thornhill, the Joint Magistrate and Deputy Collector, the thanks of the Government are due for his public-spirited exertions, not only in this, but also in many other works, in which he has most ably and zealously seconded the efforts of the Collector and Magistrate, Mr. F. P. Buller, for promoting the comfort of the people, and for developing the resources of the country. To both these gentlemen and others, who were, and are still, associated with them in the Local Committee, the people of the district, and through them the Government of the country, lie under a great and constantly accruing obligation, which no doubt finds its highest reward in the successful result of these benevolent efforts.

3.—As the chief labor and responsibility of this work seems to have rested on Mr. C. B. Thornhill, you will be pleased to communicate to him through the Local Committee the thanks of the Government.

No. II.—*Report by* C. B. THORNHILL, Esq., C. S., *(Secretary, Road Fund Committee,) on the building of the* RANEE'S *Bridge at Sindhowlee Ghaut, Shahjehanpore.*

In the early part of the year 1845, the Ranee of Powaine, who is in possession of extensive estates, about 16 miles north of the station of Shahjehanpore, applied through the Collector for a loan from Government of Rs. 21,000 for the purpose of building a masonry bridge over the river Kunout, which runs across the road from Powaine to the station and city; and at the same time requested the Road Fund Committee to undertake the work for her.

2.—The sanction of Government having been received on both points, the Committee at once applied to the Superintending Engineer, Colonel Abbott, submitting for his approval their design, which consisted of 5 arches of unequal spans, giving a total waterway of 170 feet, of which the largest being placed in the centre, raised that part of the bridge above the flanks, the object being to allow of the passage of boats under the bridge during floods, and at the same time save the heavy expense of embanked approaches.

3.—Colonel Abbott, while he approved of the plan sent up by the Committee, suggested the great advantage in appearance which a bridge gains, by having the arches of equal size, and the lines of the parapets, &c. parallel to the horizon, and urged that the additional cost of the embankment would be amply repaid by the effect which would be gained. At the same time he sent a design of his own, which was immediately adopted by the Committee. It consisted of three arches of equal span and rise, giving a total waterway of 150 feet; Colonel Abbott also expressed a wish, that masonry blocks, which have been found to succeed so well upon the Ganges Canal, should be adopted in the foundations.

4.—The design having been determined upon, the next point to be considered, was the site. The course of the river Kunout is very tortuous, and in the vicinity of Sindhowlee, its valley is extensive; the breadth of the flood, which rises on an average only 9 feet, being nearly $\frac{1}{4}$ of a mile. It was therefore necessary to take advantage of the ground, so as to reduce the embankment as much as possible.

5.—The river has never been known to shift its bed, which being composed of a tenacious clay over which the water seldom flows with any rapidity, there was little danger to the bridge to be apprehended on that score.

6.—To ascertain the rate at which the floods passed through the valley, advantage was subsequently taken of the construction of the Bridge of Boats at Lodheepoor, eight miles below Sindhowlee, to contract the outlet of the flood to 125 feet. Through this, the greatest velocity attained by the water, was 4 feet per second; or a little less than 3 miles an hour.

7.—There being then no perceptible destructive action of the river upon its banks, the necessity for placing the bridge below a long straight reach was obviated, and the selection of the present position was caused by its proximity to high ground on the north bank.

8.—The bridge was placed at right angles to the course of the floods, without reference to the summer water of the river; which it was decided could be subsequently directed towards the bridge, by cutting a Canal through the isthmus of the reach above it.

9.—A reference to the plan of the abutments in the accompanying sketch, will shew the nature of the blocks which form their foundations. A framing of 12 saul timbers each one foot square, was constructed by laying 6 timbers in pairs, with a space of $5\frac{1}{2}$ feet between each pair at right angles, to six others similarly paired. These being let into each other by halving, a platform was produced in which there were four square apertures of about 5 by $5\frac{1}{4}$ feet each. The corners of these were again filled in so as to make the aperture octagonal. Two platforms thus formed and strongly secured with iron bolts and straps, were placed in *situ*, six feet apart, on the southern bank of the river, in an excavation which had been carried down to the water.

10.—On the 21st June 1845, the Ranee of Powaine herself proceeded to the spot, and (concealed by the trench) laid the first brick with much formality; the event being celebrated by a display of fire-works.

11.—Before laying the masonry upon the timbers, iron rods $\frac{3}{4}$ inch diameter were thrust through holes bored in the platform, and secured below by nuts; the upper part of the rods were then turned into loops one above the other at about 1 foot apart; and through these loops wooden staves were inserted parallel to the platform below. The masonry was then proceeded with in the usual way; the bricks laid round the octagonal apertures being dressed to a point in their centre, as in a circular well. The courses, as they rose, built in the staves, so that the platform became

most securely attached to the brick work. This precaution was found of great service, when the blocks reached a depth of about 18 feet, for the friction produced by so large a surface in contact with the closely compacted sand, through which it was sunk, rendered the descent very slow, and although the blocks were loaded above with an enormous weight, it frequently happened that the earth was entirely scooped out from below the wooden platform, so that had no precautions against such a contingency been taken it would have fallen away from the masonry.

12.—At a depth of 17 feet, a thin stratum of small nodules of kunkur was met with. It was not considered safe to leave the blocks at so small a depth upon a doubtful bed. They were therefore carried down to 22½ feet, where the kunkur assumed the form of large masses having the interstices filled with very coarse sand. This stratum was subsequently found to crop out at a distance of about 600 yards to the north of the bridge, and as it forms the support of all the foundations, the slight dip rendered it unnecessary to carry the northern blocks more than 19½ feet below the bed of the river.

13.—The operations which have been carried on in the Ganges Canal have produced such detailed reports of the mode of working the blocks, that nothing remains to be said. The large size of the blocks used in the Ranee's bridge, however, rendered the greatest caution necessary, to prevent the surface from becoming unlevel by unequal subsidence of the corners; the correction of this error being a work of great difficulty and delay at all times, and in extreme cases an impossibility.

14.—The masonry was built in stories of eight feet, the second story commencing after the Kachees had brought the top of the first to the level of the water by sinking.

15.—The piers were founded upon double lines of cylinders as they were thought to be more manageable than large blocks, when the adjustment and commencement of the work was necessarily under water. The four abutment blocks and 16 pier-cylinders having reached the bed of kunkur before alluded to, were filled with chippings of bricks, kunkur, refuse of the lime-kilns, and fine sand, about one foot at a time being filled in, and closely rammed. The apertures were then closed with flat vaults, the surface of the dome being on the level of the bed of the river. To effect this, it was necessary to employ gangs of men night and day to bale the water, so as to keep the masonry from being submerged until the mortar had set.

16.—The two blocks forming each abutment were then connected by an arch, and the masonry continued to a height of 9½ feet, a double arch was also introduced in the body of the piers, so as to throw the weight of the bridge upon the centre of the cylinders, and relieve the vaulted spaces between them.

17.—Having observed the great difficulty of preventing some settlement in retaining walls, by which an unsightly crack is produced in the parapet, a cylinder was sunk in the line of each wing wall, about 10 feet to the rear of the abutment; 12 feet beyond this, short piles were driven and covered with stout planking; arches were then thrown from the abutment to the cylinder, and again from the cylinder to the piles; so that the enormous weight of the wall, which is 29 feet to the top of the parapet, is divided upon three strong points, instead of being thrown upon the insecure soil, which immediately adjoins the bed of the river.

18.—The alterations in the bed of the river, caused by the sinking of the cylinders had by this time distributed the water between two of the piers, leaving only one arch dry at the commencement of the year 1847. It therefore became necessary to construct two centres, which should offer no obstruction to the floods, should any

accident protract the completion of the arches beyond the commencement of the periodical rains.

19.—The following design was accordingly selected, as combining the greatest strength with simplicity.—*Vide* Sketch II.

20.—When, however, it was erected, the joints were found so defective, in the nicety so necessary to ensure strength by an equal distribution of the strain upon every part; and the skeleton centreing first put up, having fallen, in consequence of the neglect of the carpenter to brace it at once, the supports, *Figs. 2 and 3* were added, the former under the southern, and the latter under the middle arch.

21.—The northern space was nearly filled with great masses of sun-dried bricks, and a pattern having been traced on the ground, and built upon 6 inches, in relief as a guide, the southern and centre arches were commenced together, and after advancing a third together, the whole of the masons were put upon the former, so as to complete it at once, and enable the massive centreing, which would oppose so great an obstacle to the floods, to be removed. The north arch having been keyed in May, was at once brought to its bearings by a very clever suggestion of Cheda, the head mason.

22.—The support was composed of pillars of sun-dried bricks only. Upon flooding their foundations, they yielded to the superincumbent weight of the arch, which gradually settled 3 inches, within 8 hours of being keyed; the subsequent settlement was not quite half an inch, being nearly 3½ inches altogether. This, although trifling, compared to the settlements which took place in many stone bridges under celebrated French Engineers, is nevertheless large, and as will be seen, greatly in excess of that of the other arches.

23.—On the completion of the northern, the middle and southern arches were proceeded with. The former, being kept in advance, was completed some days before the latter, and the centreings were lowered by driving out wedges, the moment the arch was keyed. Although the method of inserting these wedges was very rude, compared with that adopted in England, yet, they were found to answer the purpose designed; while the want of skill in the carpenters prevented the attempt of any thing more complicated. The settlement of the middle arch was 2 inches; that of the southern barely 1 inch.

24.—The completion of the arches and removal of the centreings before the occurrence of any severe flood, prevented any hindrance to the navigation of the river; but the rise of the water, and consequent submersion of the wing wall foundations combined with the cessation during rains of all brick-making, threatened to delay most seriously the progress of the works. Most opportunely at this juncture, the materials of a distillery, belonging to the late firm of Barron and Co., situated upon the river Kunout, about 40 miles above the bridge, were offered for sale. The committee at once became the purchasers of the bricks, upwards of 5 lacs of which were floated down the river before the cessation of the floods, and as soon as the traffic of carts recommenced in September, the bridge was so far advanced as to admit of their being alluded to pass over it.

25.—The work was continued from this time without any interruption, or the occurrence of any incident deserving of notice, and finally completed on the 9th April 1848.

26.—The embanked approaches were commenced in October 1846, and carried up in layers, 5 feet at a time, in order that this foundation of the road might be gradually consolidated by one whole rainy season, and even with this precaution

when the road had been completed and traffic on it commenced, the subsequent subsidence, by consolidation, was so great, as to cause considerable inconvenience, and require constant repair; nor can it be hoped that this mound of earth (upwards of 25 feet high at the bridge) will be kept in an efficient state of repair, without constant care and attention for some years, and the protection of the grassed slopes from the action of the rain by the construction of low walls on each side of the road, having in them apertures, leading to tiled or masonry shoots.

27:—The local circumstances, under which this bridge was erected, were upon the whole very favorable. Excellent kunkur for lime was produced within ¼ mile of its site. A good foundation of kunkur was found at 22½ feet below the bed of the river. Charcoal for burning the lime was obtained at a cheap rate from the forests in the north of the district. Timbers for the centres passed down the river during the floods, thereby saving all expenses of land-carriage. And lastly, any number of excellent brick-layers was at all times procurable from the city.

28.—The trusses which formed the centreings, although composed of heavy timbers, were raised with great facility in the following manner. The piers being raised to the intended height and levelled, a large boat, 30 feet beam, was floated between them. Upon this a strong scaffolding was erected, and a platform laid upon it, rather above the piers. To this platform, the timbers were raised singly and then joined together, the feet of the rafters laying upon the temporary piers, upon which the centreing was afterwards to rest, in the position they were intended to occupy permanently. The collar-beam and iron-tie having been adjusted, the united efforts of about 20 men raised the truss which was secured by guys. The boat was then shifted down the stream, and a second truss raised and secured by wooden braces to the first. The main trusses having been raised and secured, the smaller trusses were adjusted above them, and similarly braced, the form of the arch was approximately given by curved pieces of mangoe wood laid upon the upper trusses, across them bamboos were secured in the usual manner, and the correct curve obtained by a layer of clay protected by a thin coating of mortar.

29.—In turning the arches, the correct radiation of the voussoir courses was secured by the erection of a wooden railing on either edge of the centreing, the bannisters of which were *radii* to the curve, and a correct plan of half the arch in relief was constructed upon the ground, close to the arch, from which the work was verified from time to time as it advanced.

30.—The bricks for the arches were most carefully selected; only those of the deepest red being used.

31.—In the southern arch, which was first turned, the mortar was not ground more than 4 hours, in the expectation that by carefully keeping the masonry well moistened until the keying of the arch, and striking the centreing instantly, the enormous compression to which it would be then subjected, would bring the bricks into actual contact, and ensure a perfect consolidation of the mass. When, however, the versed sine of this arch was found to have diminished 3½ inches, the possibility of the alteration of the form of the curve in coming to its bearings rendered the repetition of the experiment unadvisable; the mortar was therefore continued in the mill 8 hours for the second arch, (in which the settlement was found to be only 2 inches,) and for 12 hours in the third arch, where the versed sine was found to have been lessened only one inch.

32.—In stone bridges, where the voussoirs are composed of a single stone, the elasticity of the wooden centreing causes each joint to open and close in succession, as the gradual addition of the weight produces a change in the form of the centre.

33.—In this bridge, however, the whole effect appears to have accumulated at one point. For when about 13 feet of the arch had been laid, the extrados at about the 40th course commenced opening, and the joint continued to separate until the arch had advanced to about 10 feet, when the direction weight being altered, the aperture then about 1½ inch wide, gradually decreased until, on the keying of the arch, it nearly closed. In consequence of the voussoirs being composed of so many pieces, it did not entirely close, but after the centreing was removed, there was still a distinguishable crack.

34.—The highest flood level has been placed at the springing of the arches, but although such floods are reported to have occurred, the highest within the last 8 years has not reached within 1 foot of the height of the piers. It was mentioned above, that the breadth of the flood was nearly ¼ mile, this however arises partially from the flood level of the river Ghurra being higher than the Kunout, which flows into it. The cause of this is probably the excessive falls of rain in the hills, where the Ghurra rises; the Kunout on the other hand having its source within the Shahjehanpore district, receives only the drainage of the immediate neighbourhood.

35.—Instead then of receiving the superfluous stream of the Kunout, the Ghurra actually pours some of its own flood into it, causing a counter-current, which is felt as high as the city of Shahjehanpore, and a heading up of the stream which is felt above Sindhowlee.

36.—The actual flood section, for which it was necessary to provide an outlet at the bridge, may be taken at about 1,400 feet, and as this is less than the area of the section of the bridge without the arches, it is to be hoped that no heading up of the water, and consequent destructive action of the current upon the bed below the bridge need be apprehended.

37.—Previously to the setting in of the rains of 1847, the intended canal was cut through the neck of land formed by the bend of the river above the bridge, and the old channel bunded across, so that the bridge is now at right angles to the permanent bed of the river, as well as to the direction of the floods.

Statement of Charges incurred in constructing the Sindhowlee Bridge for the RANEE OF POWAINE.

1.—DIGGING FOUNDATION.					
87 Coolies from 1 to 2 annas each, -- --	9	9	6		
Digging 26 square yards, @ 6 pie per yard, --	8	3	3		
				17	12 9
Platforms, (Square.)					
24 Timbers, at different rates, -- -- -- --	420	9	5		
32 maunds of Iron, @ 5 Rs. 7 as. 6 pie, and Rs. 9 per maund, -- -- -- -- --	193	2	3		
40 Blacksmiths, from 2 as. 6 pie to 4 as. each,	80	0	0		
1,117 Carpenters, from 2 as. 6 pie to 4 as. each,	163	6	3		
Sawyers for 258 pieces, @ 12 and 13 Rs. per 100 piece, -- -- -- -- -- -- --	31	0	11		
20 Kirbs, @ 7 Rs. 3 as. 2½ pie each, -- --	144	0	0		
				1,102	2 10
					1,119 15 7

Brought forward, -- --				1,119	15	7
Masons for making Cylinders.						
2,294 Masons, from 1 to 4 annas, -- -- --	571	11	3			
5,408 Coolies for aiding Masons, from 6 pie to 2 annas 6 pie, -- -- -- -- -- --	459	11	9			
9,902 Coolies for lifting up mud, from 2 annas to 2 annas 6 pie, -- -- -- -- -- --	1058	2	3			
2,64,460 Bricks, @ 538 Rs. 12 as. 7 pie per lac,	1423	7	4			
7,000 mds. of Kunkur lime, @ 10 Rs. 13 as. 10 pie per 100 maunds, -- -- -- --	757	10	6			
400 mds. of Stone lime, @ 15 as. 3½ pie per maund, -- -- -- -- -- -- --	382	11	1			
Sinking 88 feet 1½ inch Blocks, @ 4 Rs. per foot,	352	8	0			
Ditto 59-0-10 feet diameter at 1 Re. per foot,	59	0	0			
Ditto 232-6-8 feet ditto, @ 14 as. per foot, --	203	3	0			
Ditto 47-0-7 feet ditto, @ 12 as. per foot,	35	4	0			
Miscellaneous Charges, -- -- -- -- --	671	8	5			
				5,974	13	7
						7,094 13 2
2.—Piers.						
1,057 Masons, from 1 to 4 annas, -- -- --				248	1	6
2,887 Coolies, from 6 pie to 2 annas, -- --				268	8	3
1,40,000 Bricks, @ 538 Rs. 12 as. 7 pie per lac,				754	8	10
3,000 mds. of Kunkur lime, @ 10 Rs. 13 as. 10 pie per 100 maunds, -- -- -- -- --				346	9	4
2,500 mds. of Stone lime, @ 15 as. 3½ pie per maund, -- -- -- -- -- -- --				240	9	10
						1,858 5 9
3.—Centreing and Arches.						
Centreing.						
40 Timbers, @ different rates, -- -- -- --	761	7	0			
1,595 Carpenters, from 2 to 4 annas, -- --	400	0	0			
760 Blacksmiths, from 2 annas 6 pie to 4 annas,	134	10	1			
Sawyers, for 595 pieces, @ 12 and 13 Rs. per 100 pieces, -- -- -- -- -- -- --	71	4	9			
15 mds. of Iron, @ 8 and 9 Rs. per maund, --	139	6	3			
81 large iron Screws, @ 6 as. each, -- --	31	6	0			
1,00,000 kucha Bricks, @ 4 annas per 1,000,	25	0	0			
Miscellaneous Charges, -- -- -- -- --	720	1	9			
				2,283	3	10
Arches.						
4,588 Masons, from 1 to 4 annas, -- -- --	941	10	9			
10,348 Coolies, from 1 to 2½ annas, -- --	1,134	14	0			
1,50,000 Bricks, @ 538 Rs. 12 as. 7 pie per lac,	808	7	9			
3,400 mds. of Kunkur lime, @ 10 Rs. 13 as. 10 pie per 100 maunds, -- -- -- -- --	368	4	10			
400 mds. of Stone lime, @ 15 annas 3½ pie per maund, -- -- -- -- -- -- --	382	11	1			
Miscellaneous Charges, -- -- -- -- --	95	2	3			
				3,731	2	8

4.—Parapet.					
2,318 Masons, from 1 to 4 annas, -- -- --	505	5	9		
5,716 Coolies, from 1 to 2 annas, -- -- --	564	0	9		
15,080 mds. 20 srs. of Kunkur lime, @ 10 Rs. 13 as. 10 pie per 100 maunds, -- -- --	1,632	14	1		
415 mds. 13 srs. 6 cks. of Stone lime, @ 15 as. 3½ pie per maund, -- -- -- -- --	400	2	0		
5,15,200 Bricks, @ 538 Rs. 12 as. 7 pie per lac,	2,776	13	11		
Miscellaneous Charges, -- -- -- -- --	514	13	11		
				6,394	2 5
5.—Plastering.					
3,961 Masons, from 1 to 3½ annas, -- -- --	762	13	3		
4,735 Coolies from 1 to 2 annas, -- -- --	494	15	0		
10,000 mds. of Kunkur lime, @ 10 Rs. 13 as. 10 pie per 100 maunds, -- -- -- --	217	4	8		
207 mds. 26 srs. 10 cks. of Stone lime, @ 15 as. 3½ pie per maund, -- -- -- -- --	200	1	0		
Miscellaneous Charges. -- -- -- -- --	78	15	9		
				1,754	1 8
6.—Approaches.					
15,31,028 cubic feet road, @ 3 as. 6 pie, 3 as. 9 pie and 4 annas per foot, -- -- -- --	3,768	8	6		
2,028 Coolies for sloping sides from 1 to 2 annas,	208	12	0		
A dam from bridge to west, -- -- -- --	60	0	0		
134 Coolies for making dam from 1 to 2 annas,	16	5	9		
Compensation for owners of land, -- -- --	93	12	0		
1,350 mds. of Kunkur for laying over the bridge, @ 1 Re. per 100 maunds, -- -- -- --	13	8	0		
				4,160	14 3
				27,276	11 9
Deduct realized from sale of wood, &c., employed in centreing, -- -- -- --				1,276	11 9
Total, Co.'s Rs.				26,000	0 0

C. B. THORNHILL.

ELLIPTICAL TUNNEL BRIDGE AT SEONEE.

Letter No. 3662, dated Allahabad, 9th March 1849, circulated by MAJOR A. H. E. BOILEAU, *Superintending Engineer, Central Provinces.*

SIR,

I have the honor of forwarding, for your use, a plan of the ELLIPTICAL BRIDGE, built at my suggestion, by Lieutenant D. Briggs, Executive Officer of the Great Deccan Road in 1847-48, one mile southward of the station of Seonee; and which, after having been exposed to the action of two monsoons, or rainy seasons, has been found to answer its intended purpose, admirably; viz., to substitute a cheap tunnel, with scarcely any foundations at all, in place of the ordinary kind of bridge, with massive and costly foundations, which have usually been considered necessary in bad sites, and specially on the black cotton soil of Malwa and Gondwarra.

2.—The Elliptical Bridge, of which the plan is herewith circulated, has a waterway of 10×6 feet, with a tunnel about 22 feet long and 1½ feet thick, lying upon a thin bed of concrete, (as shown in the drawing,) and without any other foundation, than a front and rear drop-curtain of 2½×2½ feet section, by which the stratum of black soil, under-lying the concrete, is maintained in a compact state; and any cutting away of the bed of the nullah by the current is guarded against: though this had been partially provided for by sinking the flower of the tunnel, nearly a foot below the natural bed of the stream.

3.—The cubic contents of this bridge are 1,258 feet of plain masonry, (burnt bricks set in lime mortar,) and 1,030 feet of Elliptical masonry of the same kind; the whole being plastered as usual, and costing Co's Rs. 248-10-0. The kind of bridge, for which it was intended as a substitute, was to have cost Rs. 640; the tunnel being 24 feet long, the parapets 2″ thick, with a roadway of 20 feet; and a waterway of 10×7 feet; so that the difference in point of cost is most strikingly in favor of the elliptical bridge.

No. II.—*Extract of a Note, from* CAPTAIN J. R. OLDFIELD, *Executive Engineer, 5th Division, Agra, on* MAJOR A. H. E. BOILEAU'S *Tunnel Bridge for small spans, dated Agra, 5th April 1849.*

The concrete, I am in the habit of using, consists of,

One part,—Well ground mortar; made with kunkur, lime, and bujree or coarse sand; in the proportion of one of the former, to two of the latter:—

One part,—Coarse bujree or gravel;—

Two parts,—Well burnt brick, broken up into pieces which would pass through a ring of 1½ inch diameter.

The mortar, gravel, and broken brick, to be intimately mixed in small heaps, so as to preserve their relative proportions throughout the mass. The mortar should be used quickly, as it comes from under the rollers, and never allowed to dry till the work is complete.

The concrete may be laid down in layers of from 6 to 9 inches thick, and beaten with heavy rammers, whilst thoroughly wet, and before being allowed to set. In case of more than one layer being required, the lower one should not be allowed to set before the upper one is added.

The bottom of the excavation may also be well rammed before the concrete is laid down, should the soil be compressible by the blows of an ordinary rammer.

No. II.—*Description of the Wooden Bridge referred to in the preceding letter, enclosed in a communication from* MR. H. BIGGE, *to the* SECRETARY *Military Board, Fort William, forwarding model of a Wooden Bridge built at Singapore.*

The bridge from which the accompanying model is taken is one erected at Singapore, on the road leading to the north of the town across a small stream. The length of the span between the support is 59 feet, the breadth 10 feet, height of sides 7 feet. The whole is constructed of planks, with the exception of two posts at either end, and the sleepers on which the roadway platform is supported. The bridge was constructed by Captain Stevenson, M. N. I., Executive Officer, from a description of an American bridge of somewhat similar, but considerably more complicated nature (which was erected by an Officer, U. S. Army), consisting of 9 arches of 130 feet span each, and over which the turnpike road is carried on the lower level (or that of the bank of the river,) while the train-road of a railway is carried above, forming a double bridge of 1,170 feet in length. The materials used by Captain Stevenson in constructing this novel, if not unique bridge, at Singapore, were slabs and other similar planks, &c., the refuse of the timber-yard, fastened together with wooden pins; iron-bolts with screw nuts being used where the diagonal planks meet the iron ones; one to each, so as to bring the frame together in the closest manner. Besides these no iron was used, or other material than wood.

The planks used are 1 inch by 12 or nearly so, and, at the ends of the bridge, are received into the supporting posts cut out for that purpose, and then pinned together.

The horizontal planks when being placed, require that care should be had to prevent their being joined at the same spot, or elsewhere than in the middle space between two of the diagonals, when the joints being accurately fitted they are kept in their places by the pins. The sleepers are placed apart from each other 10 inches, the distance between the diagonal planks being 20 inches; such sleepers as are placed between the diagonals are notched, so as to allow of their ends overlapping the horizontal planks, and thus form binders to prevent the latter from bulging out on any great pressure being applied. Over these sleepers, planks are nailed diagonally to form the roadway. The diagonal upright planks are pinned together at the point of contact in the centre, as well as above and below. The roof is a light one of leaves, as generally used in the Straits.

Mr. Thompson, Civil Engineer, Singapore, told me he was prepared to construct bridges on this principle, 130 feet span for about Rs. 700 each.

The model is on a scale of 1 inch to a foot, and represents therefore a bridge 21 × 12. It has been proved with 276¾ lbs. placed on it, a trifle less than 2½ cwt., which caused it to yield equal to 3 inches, but the model received no injury. The expense of such a bridge of the very best materials at Moulmein is about Rs.10 per running foot; one of the size of the model would cost Rs. 193-7-4, and requiring no greater degree of skill in erecting than that possessed by the most ordinary description of workmen; hence it is likely to prove useful in countries where wood abounds, as even should plank not be available, small trees, if care was taken in fitting them at the points of contact, would answer equally well. The traffic over the bridge at Singapore is very considerable. Buffaloes with heavy carts are continually passing and re-passing all day, and had done so for two months ere I left, without damage to the bridge in the slightest degree.

The bridge is a temporary one built to keep open the road, whilst the pucka one is being re-built, and hence the use of inferior material to save expense; the cost I believe did not exceed Rs. 60 or 70.

DESIGN FOR A BRIDGE OVER THE NURBUDDA NEAR JUBBULPOOR.

By Lieut. David Briggs, *Surveyor, Jubbulpoor and Kamptee Road.*

Specification, *for the construction of a* Timber Bridge, *with stone piers and abutments, across the river* Nurbudda, *at* Gawarie Ghat, 3¾ *miles distant from the station of* Jubbulpoor, *on the* Great Deccan Road.

1.—Length of Bridge.—The bridge will be 970 feet in length, divided into ten bays; the distance between the centres of the piers being 97 feet.

2.—Abutments.—The south abutment shall be built 15 feet horizontally, and 12 feet vertically, into the bank, which is composed of very stiff clay. It shall be built in steps towards the rear, so as to give it a batter of 6 inches in 18, until it has acquired the requisite breadth of 15 feet; below which the foundation will be carried down 12 feet, at an angle of 35°, built in steps of 12 inches wide and 18 deep, as shown in Fig. 3. The north abutment will be sunk into the bank 15 feet vertically, with a base of 14 feet, protected in the rear by four steps of 18 inches in breadth, and 3′ 9″ in depth. The face will also be secured by four steps of one foot each.

3.—Piers.—The foundation of each pier, shall be sunk until it rests either on rock, or such hard compact soil, as to place any chance of shifting out of the question. The masonry shall be laid in courses of two feet in thickness, decreasing in steps of 12 inches wide and 18 high, towards the level of bed of river. The piers shall be 40 feet high, 10 feet wide at foot, and four feet at top; 28½ feet long at bottom and 17 feet at top; having the up-stream face protected by the blocks of stone, composing the column, being laid so as to form a cut-water projecting one foot.

The down-stream face will be built in ten steps, one foot wide and four feet deep, (*vide* Fig. 2,) so as to form a buttress offering the greatest resistance to the volume of water rushing down on the pier, as also affording an easy means of ascending or descending to any part of the piers that may require repair.

4.—Material.—The whole masonry used will consist of blocks of dressed sandstone laid in regular courses; the mortar of stone-lime mixed with river sand, in the proportion of two measures of the former to five of the latter.

5.—The principle on which the superstructure of the bridge will be constructed is that entitled the "double truss" invented in 1835 by Ithiel Town, an American Engineer, and that it may be understood how much it is practised, and how well it answers, I have in Appendix A., given a quotation from Mr. Weale's work on bridges, which mentions a few of the instances where the principle has been successfully adopted in crossing rivers of great size. I may here mention that the bridge herein specified shall be of sufficient strength to bear the weight of an engine, and train of loaded carriages.

6.—The bridge will be constructed of a double truss on each side of the roadway as shown in Fig. 3. Each truss will consist of a series of diagonal braces 10″ by 3″ inclined at an angle of 47° crossed by another series inclined at the same angle in an opposite direction, and of a horizontal string-piece 12″ by 3½″ on each side at top and bottom; the whole being firmly secured by trenails of babool wood 1½ inches in diameter.

The height of the truss will be 9 feet; being little less than one-tenth of the distance between the piers. Each double truss will be further strengthened at foot by three wall-plates, each 14″ by 9″ pinned into the truss frames, and the whole secured by iron straps 2″ by ¼″ passing round both wall plates, and string pieces at every ten

feet. Fig. 2 shows the way in which the double trusses will be put together with string-pieces between them, and the wall-plates at foot; and Fig. 1 gives a horizontal section, showing how the trenails connect each string-piece and truss.

At every five feet, tie-beams 9″ by 9″ will connect the lower part of the double truss frames with each other; and at every 5 feet on the top of the frames at C.C.C. (erroneously shown in Fig. 3, as on the top of the crossing of the truss braces at *d,d,d,*) floor beams 9″ by 9″ shall be placed, connecting the truss frames together at top. Every second floor beam shall extend 3 feet beyond the verge of the roadway, to receive the struts of the railing stanchions at right angles to the floor beams; and pinned into them will be laid roadway beams 7″ by 7″ at every 3 feet. The flooring will consist of 3 inch planks extending across the whole surface of the platform, and two skirting boards, 5 inches high, and 2 inches thick will be set up along the edge of the planking, to confine the road metal which will be laid on 5 inches thick.

The railing will be 5 feet high with stanchions 5″ by 5″ let into the floor beams and propped up by stout struts at every 10 feet. The stanchions shall be connected together, by a top and two diagonal braces, of a scantling of 4″ by 3″.

7.*—Approaches.—In the estimate I have allowed 15 feet of wood-work on either side for the approaches to the bridge, which, however, will scarcely be necessary, as they will be cut out of the solid stiff clay.

8.—Description of wood used.—All the wood required for beams, wall-plates, truss braces, &c. shall consist of well-seasoned teak, and the whole of the wood used in the bridge will be steeped in a solution of corrosive sublimate for the space of 7 days.† All the wood used in this bridge will be cut up on the spot by a saw-mill driven by water, of a very cheap and simple construction; a description and plan of which are given in Appendix B.

* *Note.*—I had at first intended to enclose the whole wood-work of the bridge by a covering of plank, as represented in Fig. 3, but as the expense would be very heavy (about Rs. 44,000,) and I believe incommensurate to the advantages gained, I shall omit any mention of it in this specification.

† *Note.*—I have been deterred from making provision in this specification for either painting, or paying with dammer, the wood-work of the bridge, by the written testimony of so many experienced Officers of the Engineer Department, both in this country and in England, "which goes to prove" that "painting or paying is one of the greatest causes of decay in timber, as it completely prevents the air from acting on the wood," thereby keeping all moisture within, which of itself is sufficient to decay it.—*Professional Papers of the Royal Engineers, Vol. V., page* 282.

ESTIMATE, *framed by* LIEUT. DAVID BRIGGS, *of the probable expense that would be incurred in building a Bridge, of ten bays, on the "double truss" principle, across the river Nurbudda at Gawarie Ghat, near Jubbulpoor, on the Great Deccan Road; according to the foregoing specification and accompanying plan, Agra, 29th March 1850.*

NUMBER.	DESCRIPTION.	COMPANY'S RUPEES.					
		Rs.	A.	P.	Rs.	A.	P.
8877724	Cubic feet of masonry in abutments and piers, at Co's Rs. 14-0-0 per 100 cubic feet,-- --	12,428	13	3			
6000	Running feet of teak timbers 14″ by 9″ at 0-2-0 per foot, -- -- -- -- -- --	750	0	0			
8000	Running feet of teak string-pieces 12″ by 3½″ at 0-1-6 per foot, -- -- -- -- -- --	750	0	0			
1600	Trusses 14½′ by 10′ by 3″ at 0-12-0 each, --	1,200	0	0			
206	Tie-beams 18′ by 9″ by 9″ at 1-0-0 each, --	206	0	0			
206	Floor beams 22′ by 9″ by 9″ at 1-4-0 each, --	257	8	0			
6000	Running feet sleepers 7″ by 7″ at 0-1-0 per foot,	375	0	0			
412	Braces 10′ by 5″ by 5″ at 0-10-0 each, -- --	257	8	0			
210	Iron straps, (screws included,) 9′ by 2″ by ¼″ at 2-0-0 each, -- -- -- -- -- --	420	0	0			
15916	Superficial feet of 3″ planking 15′, 10″ wide at 0-3-0 per superficial foot, -- -- -- --	2,981	4	0			
2000	Running feet of skirting boards 5″ by 2″ at 0-1-0 per foot, -- -- -- -- --	125	0	0			
2000	Running feet of rails 5′ high with stanchions 5″ by 5″ at every 10 feet at 0-8-0 per foot, --	1,000	0	0			
15916	Superficial feet of road metal at 1-8-0 per 100 superficial feet, -- -- -- -- -- --	238	11	10			
	Trenails and iron work not included in the above, -- -- -- -- -- -- -- --	1,500	0	0			
	"Kyanising," the whole of the wood-work,	1,000	0	0			
					23,492	13	1
	Total, Co.'s Rs. --				23,492	13	1
	Total Contingencies, at 5 per cent. --				1,124	10	3
	Total, Co.'s Rs. --				24,617	7	4

This includes the fitting and setting-up of all the wood-work.

APPENDIX A.

Double Truss Bridges.

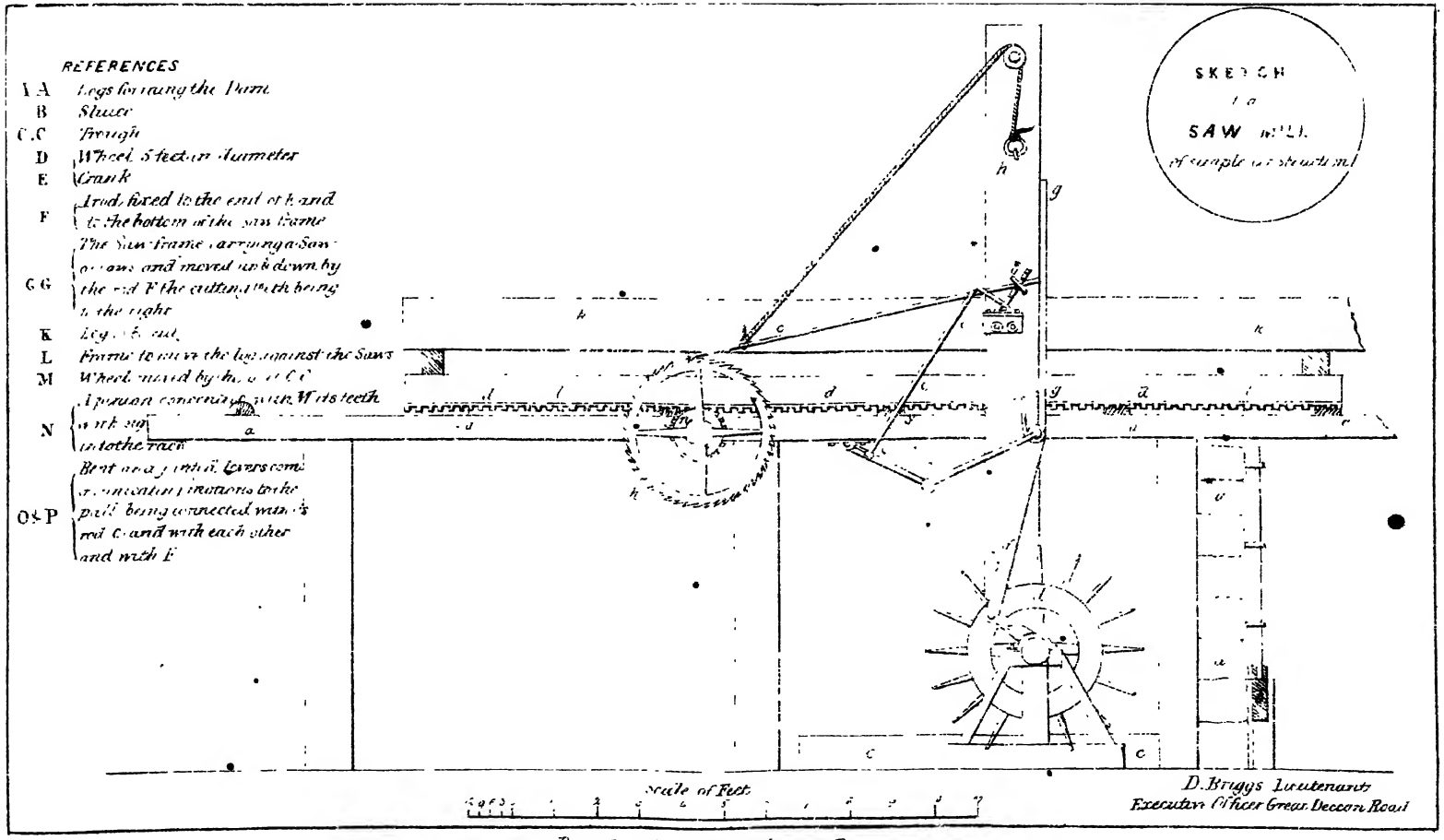
The following is quoted from the description given of the "double truss" bridges in Mr. Weale's work.

"In America there are already many of these bridges on a scale of magnitude "truly gigantic; among the most important of these is the one erected by the cele- "brated Engineer, Moncure Robinson, Esq., for carrying the Richmond and Peters- "burgh Railway across the falls of James' River at Richmond. The length of this "bridge across the river is 2,900 feet, and the trusses are supported on eighteen gra- "nite pillars, the distances between the piers varying from 130 to 153 feet. The "piers are founded on the granite rock over which the rapids flow. Their height "above the surface of the water is 40 feet, and they are carried up with a batter of "1 inch in 2 feet vertical, up to this height of 40 feet above the water, where their "dimensions at top are 4 feet in breadth by 18 in length. The floor in this bridge "is on the top of the truss frames, and the depth of these being 20 feet, the road- "way is carried horizontally across the river, at an elevation of 60 feet above the "water. This bridge was completed in September, and its cost was about £21,200 "sterling. In addition to this great work on Mr. Town's principle, executed by Mr. "Moncure Robinson, may be mentioned another on the same principle across the "Susquehannah, 2,200 feet in length with spans of 220 feet; besides several others. "These bridges may be constructed of any kind of timber, however soft, provided "planks of about 27 feet in length can be sawed out of it: while pine, spruce, and "poplar, have been extensively used in America; but oak is objected to, on account "of its tendency to spring or warp, if not well seasoned."

APPENDIX B.

Vertical Saw-Mill.

The annexed sketch of a cheap and simple vertical saw-mill, in common use in America, will show the means I intend employing in cutting up the large quantity of timber, I shall require in the construction of the work above treated of. The following references to the sketch will make the whole construction perfectly clear. A., the dam, formed of squared logs resting against a standard 12″ by 12″ struted from the rear; the dam being filled to the requisite height by a bed from the Nurbudda: provision being made to carry off the surplus water. B., is the sluice, 5 feet broad, 18 inches high, and 4 inches thick; which, when it is wanted to work the saws, is raised, and admits the water into the trough, C., to the wheel D., whose outer diameter is only 5 feet, in order that the velocity of the water may give it as many revolutions as possible, consistent with the necessary power, and thus enable the saws to make as many strokes as the wheel makes revolutions. The length of the wheel is 5 feet. E., a crank on the wheel-shaft, to which is fixed the connecting rod F., (which is fixed to the bottom of the saw-frame G.,) which, carrying the saw or saws, runs up and down between the standards, having an alternating motion communicated to it, to the extent of the double length of the crank-arm. E., K., is the log to be cut. It is mounted on the frame L. which has a rack *d*, *d*, fixed upon its under surface, and which is supported by the rollers *a*, *a*, *a*, *a*. The pinion N., on the axis of the wheel M., works in the rack; and, according as the wheel moves forward and backward, works the frame towards or away from the saws. Motion is communicated to the wheel by the pall *c*, *c*, (which may be lifted out of gear, when necessary, by the rope and ring H.,) and the other end of which is pinned into one of the holes in the arm of the bent lever O. This lever is moved backwards and forwards by the rod *e*, *e*, which is jointed to the bent-rod P., fastened at one end to the frame of the building, and at the other to the frame carrying to the saws. In this mill I intend using three saws at once. Almost all the parts, which in this sketch are shown as of iron, may be made of hard wood; and I believe that the mill may be set agoing for about Rs. 100. At a very moderate calculation, it may, with the assistance of two coolies, saw up 2,000 running feet of timber per diem,



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DURABILITY OF TIMBER USED IN FORMING BRIDGES.

No. I.—*Extract (paragraphs 83, 84 and 85) of a Despatch from the Honorable the Court of Directors, dated 15th February 1850, enquiring with reference to the construction of two Bridges, between Bareilly and Budaon, what precautions had been taken to protect the timber from white-ants and dry-rot.*

Paragraph 83.—"These bridges are to be constructed partly of timber; the object of the Committee of the Bareilly Road Fund being to open communications throughout the District as quickly as possible, which, from the cheapness and abundance of timber, they expect to accomplish within three years.

84.—"The practice of forming bridges composed partly of timber, has in some cases, as appears from the letter of the Secretary of the Local Committee, dated 20th February 1847, effected a saving of three-fourths in the cost of their construction as compared with masonry bridges, and they are found fully equal to the heaviest traffic.

85.—"This is satisfactory; but we should wish to be informed what method has been adopted in order to protect the timber from the ravages of the white-ant and dry-rot."

No. II.—*Report, dated 3rd May* 1850, *addressed to* GOVERNMENT, *North Western Provinces, by* HENRY PIDCOCK, ESQ., C. S., *Commissioner of the Rohilcund Division.*

SIR,

Having circulated to the Vice-President of the several Road Fund Committees of this Division, the Extract, paragraphs 83 to 85, of a Despatch from the Honorable the Court of Directors, received with your letter No. 417, dated 15th February last, I have now the honor to transmit their replies.

2.—It will be observed that numerous bridges, partly of masonry and partly of timber, have been constructed in this Division, and that although no precautions have been taken, in order to protect the timber from the ravages of the white-ant and dry-rot, beyond the common application of rosin, arsenic and oil, it does not appear to have sustained any injury.

3.—Most of these bridges have been recently constructed. There are, however, two referred to by the Shahjehanpore Committee as having existed for very long periods without any apparent injury to their timbers; one from 1747 A. D., the other from 1819.

4.—White-ants will not, I believe, attack any substance that is not in a state of repose, and the security of the timber in the bridges referred to, is, I have no doubt, mainly to be attributed to the vibratory motion communicated to it by the constant use of the bridge. Of course, none but the hardest and darkest colored portion of the timber, is employed in the construction of such bridges.

No III.—LETTER *from* J. R. BARNES, Esq., C. S., *Secretary to the Road Fund Committee of the Shahjehanpore District, to* H. PIDCOCK, Esq., C. S., *Commissioner of the Rohilcund Division, dated 15th April 1850.*

SIR

In reply to your Circular, No. 9, dated the 16th February last, forwarding copy of a letter from Government, with copy of its enclosure, the Committee would beg to state, that no provision has been made to protect the timbers used in their bridges, from either the ravages of the white-ants, or the effects of the dry-rot, beyond what is commonly applied, viz., a composition of rosin, arsenic and oil, boiled together.*

2.—At the same time, they would remark, that there are many bridges within the immediate vicinity of this city, built on this principle, viz., of combination of masonry and timber, which, though they have been built for many years, have yet, as far as the eye can judge, their timbers quite sound and entire: for example,—

1*st.*—A small bridge, combining masonry and timber in the Kukra mohullah, near to the Mudra Khel Chokey, said to have been built by Akhoon Moolla Jubbar Khan, in the years 1747.

2*nd.*—The large bridge over the Khunout, built by Hukeem Mehdee in the year 1819. In this, the timbers have been proved quite sound, when during the last year, the shape of the centre arch was lessened.

3*rd.*—Those belonging to the old Lodhipoor bridge, when broken up in the year 1846. Besides these, there are in the district many others.

3.—Facts proving, perhaps, that protection is afforded to these timbers, from the ravages of the white-ants, by the vibration caused by the passage of wheeled conveyances, &c. Of the effects of the dry-rot, but little fear need be entertained; provided a careful selection of the timber is made, and all those, in which the slightest appearance of a white vein is visible be discarded.

* In the proportion of rosin 1 seer, arsenic 2 chittacks, and oil 1 seer.

PART III.

CONSTRUCTION OF PUBLIC ROADS.

CIRCULAR ORDER *by* MILITARY BOARD, *Fort William, to the* SUPERINTENDING ENGINEER, *North Western Provinces, No. 2115, dated 6th September 1833.*

SIR,

It being considered desirable, with the view of securing uniformity in the construction of roads, that some standard rules should be observed, I am directed by the Military Board, to transmit the enclosed Circular letter on the subject, accompanied by a sheet of sections.

RULES FOR CONSTRUCTION OF ROADS.

It having been observed, that various opinions exist on the formation of roads, which might lead to much diversity in the mode of their construction, the Military Board, with the sanction of Government, have instructed me to convey to you the following observations and orders, to which, in all practicable cases, you are directed to conform.

GENERAL OBSERVATIONS.

Nature of the Country.

The nature of the country, through which a road is to be carried, will require primary attention. If hilly, the acclivities should be met with due attention to easy ascent, but without too great a sacrifice in distance.

If generally level.

If the country be generally level, but not subject to inundation, the shortest line is of course to be preferred; unless by a *detour* some important advantage may be gained, as avoiding swampy or broken ground, or bad soil, and unless, by diverging but a little from the straight line, soil of a better quality may be found.

If low and partly under water in the rains.

If the country be low, so that in the rainy season it is under water, in such a case much consideration is required, lest the road should be either too much or too little raised. It is essential that accurate levels should be taken, and the greatest height of inundation ascertained. This can only be done by personal inspection in the rains, and that is also the period when the general plan for the drainage of the country (should it be necessary to carry that through the line of roads) can best be formed.

Road through a valley.

In carrying a line of road through a valley, it will not generally be found necessary to raise it to a perfect level. It will be sufficient that the embankment shall at all points over-top the extreme height of flood, although it may dip occasionally a little, and undulate with the general contour of the country.

The natural soils best adapted for roads are those of kunkur and of gravel, and those which are formed of a mixture of clay with sand. The first and the last form excellent roads with little labor, and where they are found, it may be sometimes advantageous to sacrifice a little distance for the purpose of profiting by them.

Soils adapted for roads.

FORM PRESCRIBED FOR ROADS.

Having fixed on the line of roads, the next point for consideration is its form. That is a matter of importance, for on that depends in a considerable degree, its duration in a perfect state. If it be much raised in the centre, the rain running rapidly off it will quickly wash away its substance, and run it into furrows. If, again, it be flat, the water will not run off, but will so soften, the surface that wheel carriages will readily sink in it. These extremes must therefore be carefully avoided, and with that view, the accompanying sections have been approved of, and are communicated for your information and guidance, always keeping in mind that a road should be as *smooth*, as *hard*, as *level*, and as *dry* as possible: that is, that the rain shall not lodge upon it, but yet that it shall be nearly level.

Form, or section, of roads.

The breadth of a road must in some measure depend on the expected traffic on it. For the great western road, however, from Calcutta to Dehlie, 30 feet have been deemed sufficient, and where metalled, 11 feet in the centre, of metalling, are prescribed.

General breadth 30 feet: of which the breadth of metalling to be 11 feet.

FIGURE No. 1.—This is the section for a road carried over a high and dry kunkur or gravelly soil. This road should not be raised above 1 foot in the centre, and 8 inches at the sides, giving a centre swell of 4 to 6 inches. No sharp angle should be left, either at the verge of the embankment, or where the berm is made to slope off gently into the excavation for drainage; every angle should be rounded off, and covered with sodding, where sodding is used. In this section the natural sod will grow in the hollow for the drainage, and the cultivation may be extended up to the line of trees, thus requiring for the road, a breadth of only 48 feet.

Section No. 1.
For high, hard and dry ground.
The road to be raised 4 inches higher in the middle than at the sides in a breadth of 30 feet.
In the profile no sharp angles should be left.

If this road be metalled, 3 inches of rise in the centre will suffice, instead of 4. The depth of metal is 6 inches, and the stratum of metal is to be put on equally thick at all parts, since where roads are nearly flat they will be used at all points.

But in metalled roads 3 inches of rise in the centre will suffice; depth of metal 6 inches.

FIGURE No. 2.—This section is in all respects similar to the former, except that it is raised 18 inches in the centre, and 14 inches at the sides. The slope of the embankments at the sides should be double its height.

Section No. 2.
For dry and high ground but softer still.

Section No. 2 will answer where the ground is high and dry, but the soil softer, as mixture of clay and sand. This is good soil for roads, and needs no metalling; for although it is a little heavy in dry weather, in the rains it becomes hard and firm, and is not easily washed away. On other points you are referred to the remarks on Section No. 1.

Fifty feet are required for this road.

FIGURE No. 3.—This section is applicable to a road passing through ground that is low, and subject to inundation. The centre is raised $2\frac{1}{2}$ feet; the sides will be 2 feet 2 inches in height. The drainage excavation should be formed here as in the foregoing sections; but in propor-

Section 3.
For ground rather low.

tion as the embankment is raised, so must that excavation be extended in breadth inland, so as to furnish earth sufficient for the roads without having recourse to pits or ditches for that purpose, unless the locality shall render that preferable; for besides injury to the roads and danger to passengers from deep excavations and pits, the ground occupied by them must be lost to the cultivator; whereas the sloping drain, however much it may extend in breadth, admits of cultivation through it, to the verge of the embankment, and the road is thus formed at the least possible sacrifice of ground.

Fifty-four feet in breadth will be required for this road.

FIGURE 4.—This section is calculated for a road passing through ground still lower than the foregoing. It is raised $4\frac{1}{2}$ feet in the centre; the raised embankment to slope $2\frac{1}{2}$ feet horizontally for every foot of height, so that if the wheel of a passing carriage should go over the side of the road, the carriage would not be overturned. In other respects the same directions, as in No. 3, are applicable.

Section 4. For ground still lower.

The space required for this road in breadth, will be 60 feet, exclusive of excavation ground.

FIGURE 5.—This section is applicable to a road passing through ground still lower than No. 4 section; but may be extended to any level. The road is raised $6\frac{1}{2}$ feet; in other respects the same rules apply to this section as to No. 4. The breadth required here will be 64 feet. In all cases where road embankments are much raised, the slopes of their sides should, when practicable, be planted with the *surpat* or other strong grass. The roots bind the soil, and the bush above, whilst it covers the earth, breaks and impedes the flow of water down the slope; and thus it affords protection to the road in various ways.

Section 5. For ground still lower, but may be expended to any level.

Where roads are much raised, their slopes should be planted with strong grass.

FIGURE 6.—This section represents a road winding round, or ascending in a straight line, the verge of a hill, or descending obliquely from a higher to a lower level; the size of the side drain and the number of the under drains, will of course be regulated by the extent of hill above the road to be drained. The masonry may be of dry stone, if suitable materials can be found. The outside retaining wall must of course have openings for the drainage, and the openings should be numerous in order to diminish, as much as possible, the rush of water at any one point.

Section 6. When the road ascends the verge of a hill.

FIGURE 7.—This section represents a cut through a hill, made so as to reduce the acclivity; or it represents a descent into the bed of a nullah. This section can only apply to a short line, and requires no explanation, except in cases where metal is used, that where there is a declivity, the metalling should extend the full breadth of the road.

Section 7. Where high ground is to be cut through, or a descent made into a nullah.

METALLING ROADS.

Except in particular places where the soil is bad, it is not deemed necessary to have recourse to metalling; unless indeed the metal shall be found so near the line, as to justify the additional expense. The materials for metalling roads in this country are:—

Metalling.

Various kinds of metal.

1st, Stone.

Stone of various kinds when broken down to a proper size—the pieces should be from one inch to an inch and a half in diameter.

Gravel.—Of this there are two kinds—*pit* and *river* gravel. The former is preferable on account of its roughness, which renders it more adhesive than the smoother kind found near rivers, of which latter indeed, unless it be broken, no good road can be made. The large gravel is better than small, because after being broken from its angular shape, it is easily compressed into a solid mass, and is the most durable of all materials.

2nd, Gravel.

Kunkur.—This is also a good description of metal for roads; it is durable and naturally possesses an adhesive property; so that when properly laid down and consolidated, it seems, as it were, to grow together.

3rd, Kunkur.

Koah, or bricks, broken down to the requisite size. This is a good substitute for a more perfect material. When the bricks are made from nearly pure clay, or with only a small admixture of sand, they make good metal. If sand predominates, the brick, however well burnt, is friable and easily pulverized, and is consequently inferior as road metal. The contents of the entire kiln should be brought into use—the *jáma* or over-burnt, as well as the *peelah* or under-burnt bricks.

4th, Koah.

Sand.—Clean sand, when put upon, and mixed with, a soil of stiff clay, forms a species of metalling the quality of which has been favorably reported upon to the Board.

5th, Sand

No new road should be metalled until it has been exposed to at least one rainy season, and if it be much raised, two seasons will be still better. Before the metal is laid down, the portion of the road, that is to receive the metal, should be well smoothed; a line of brick on edge should then be laid on each side to prevent the metal when compressed from spreading outwards; but it is not considered necessary that a foundation of bricks laid flat should be used under the metal; on the contrary, the road would be better were the bricks broken into *koah*, and used in that state, rather than whole.

New embankments must be allowed to settle, before metalling.

It is very essential that the metal be well rolled or beaten down, so as to become a hard solid mass, and the smoother a road can be made the better and more durable it will be.

The metal should be well consolidated.

Drains.

When a road crosses the general slope of a large tract of country, to provide judiciously for drainage through the line of road, requires the most attentive consideration. Specific rules cannot be framed for such work; but as a general principle, it is held preferable rather to have many small drains than fewer large ones—to spread the water over a considerable space, rather than to force it into a few large channels.

Drains, and general drainage of the country.

Trees.

When trees are planted along a road, they should not be placed nearer to the artificial embankment than 9 feet; for when their branches over-hang the road, the rain which collects on the leaves, falls down in large and heavy drops, and materially injures the road; they should not be less than 60 feet from each other on the same side, and planted opposite to each other.

Planting of trees.

STANDARD PLAN

Fig 1

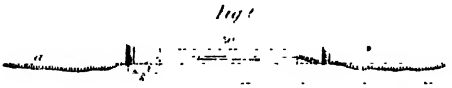


Fig 2

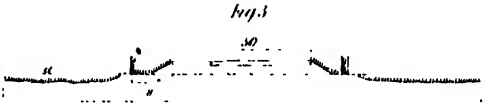


Fig 3

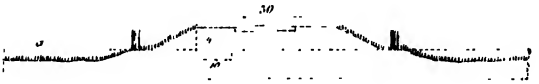


Fig 4

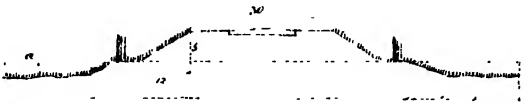


Fig 5

a a Excavation to be extended in breadth in proportion to
the quantity of earth required on the construction of the Road

Fig 7

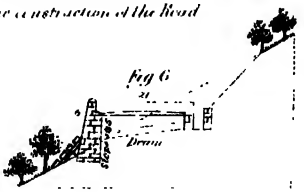


Fig 6

Drain

Sections referred to in Mr Pr's
Circular Letter of the subject
of Roads

[Signed]
Jas Taylor Lt Col
Sup.t Engineer NWP

Officers in charge of roads should earnestly encourage the desire which the people of India have, for planting trees on the sides of the highways. It is deemed by Government an important object, and it is conceived that by judicious encouragement, the people of wealth, as well as those in more moderate circumstances, would co-operate effectively in its attainment. If complete and continuous rows cannot be formed, the trees must be planted at more extended distances. In so doing, it is thought desirable rather, that a considerable vacant space should be left in the line, and then a few, say eight or ten, trees planted at the regulated distance, than that the same number of trees should be spread at equal distances over the same space. Since by the former arrangement, a large party of travellers would find shelter near together, which single trees at great distances would not afford.

Native proprietors and others should be encouraged to plant and preserve trees on the highways.

Finally, the Military Board are persuaded, that the great importance of the object which Government has in view, will be sufficiently apparent to you, to ensure the zealous and economical co-operation of yourself individually, and of the whole Department of Public Works, without which the great national benefit of facilitating communication through this extended country cannot be adequately realized.

The zealous and economical co-operation of all officers is expected in promoting this work.

Whenever circumstances may occur, which in your judgment shall render it expedient to deviate from the instructions now conveyed, you will be pleased to communicate with the Board.

CONSTRUCTION OF METALLED-ROADS AND BRIDGES,
By Local Committees.

Extract of a Letter from Lieut.-Col. A. H. E. Boileau, *Superintending Engineer, Central Provinces, No. 3562, dated Allahabad, 1st March 1849, to the address of* J. Muir, Esq., C. S., *Secretary Local Committee, Azimgurh.*

Paragraph 2.—Mr. Martin is, I think, quite right in stating that the kunkur laid upon your roads has been imperfectly consolidated, and should have been well rammed when first laid down; for though considerable traffic of iron-bound cart wheels might improve the metalling in this respect, if the tires were not too narrow, yet the continual transit of irregularly-shaped wooden wheels (which are so soft that the points of the fragments of kunkur penetrate and disfigure them), causes mutual injury to the road and to the cart wheels; and destroys the metalling in a shorter time than would otherwise have happened.

3.—I also agree with Mr. Martin in reprobating the pernicious practice of cutting deep ditches at the foot of the sloping sides of embanked roads, which, though saving a trifling part of the first cost of making a road, adds enormously to the subsequent expense of maintaining it. After allowing a fair slope for the side of the road (not less than $1\frac{1}{2}$ or 2 feet of base to each foot of perpendicular height,) a berm, or slip of level ground, should be left a few feet in width, according to the height of the embanked road, before any cutting is made for excavating soil to make that embankment.

4.—The following extract from a statement of Lieutenant D. Briggs' rates of executing various kinds of work on the Great Deccan Road may be of use to your Committee:—

EXTRACT.

Cost of cutting Jungul as executed in 1847.

Quantity of work done, -- -- -- -- -- 4,22,98,000 superficial feet.
Cost in Co.'s Rs. -- -- -- -- -- 3,686 10 $8\frac{1}{2}$
Average per 1,000 superficial feet, -- -- -- 0 1 $4\frac{3}{4}$
Average per man, -- -- -- -- -- -- -- 1,739 superficial feet;

and the distance being 150 running miles cleared to a width of 53 feet, the rate per running mile is Rs. 21-9-3.

5.—*Cost of lining and clearing Road.*

Quantity of work done, -- -- -- -- -- -- 1,05,39,620 superficial feet.
Cost in Co.'s Rs. -- -- -- -- -- 14,110 13 8
Average per 1,000 superficial feet, -- -- 1 5 5
Average per man nearly -- -- -- -- -- -- -- -- 135 superficial feet;

and the distance being 133·076 running miles 15 feet wide, the cost per mile cleared, was Rs. 106-0-7; or, if divided among the whole, 150 miles; the average would be Rs. 94-1-2.

6.—*Cost of excavating Ghats, both for Hills and for Nullahs.*

Total, -- -- -- -- -- -- -- -- -- -- -- 24,48,551 cubic feet.
Cost in Co.'s Rs. -- -- -- -- -- -- 7,192 8 3
Average per 100 cubic feet, -- -- -- -- 0 4 $8\frac{1}{2}$
Average per man about -- -- -- -- -- -- -- -- 32 cubic feet,

and Rs. 47-15-$2\frac{1}{2}$ per mile for 150 running miles.

The above rates apply to the difficult country lying between Sconce and Kamptee near Nagpoor, where even the plain earth-work required for the raising of roads costs about $5\frac{1}{12}$ annas per 100 cubic feet, which is three or four times the rate of similar earth-work near Allahabad.

7.—I have also the pleasure of subjoining for the use of your Committee various rates prevalent in the Allahabad Division, supplied by Captain J. Laughton, viz.

Pucka Masonary with 12-inch bricks of the commonest *Buharooa* lime, unplastered—

Foundation, -- -- -- -- @ 8 1 3 per 100 cubic feet, and
Superstructure, -- -- -- @ 8 5 6 per 100.

Plain Pucka Masonry roughly pointed
@ Co.'s Rs. 8 13 6 per 100 cubic feet.

Superior Masonry with 12-inch bricks, and lime mortar of fine quality, unplastered—

Foundation, -- -- -- -- @ 9 9 10 per 100 cubic feet, and
Superstructure, -- -- -- @ 10 5 10 per 100.

Superior Pucka Masonry with 9-inch bricks unplastered—

Foundation, -- -- -- -- @ 12 10 0 per 100 cubic feet, and
Superstructure, -- -- -- @ 13 1 9 per 100.

Arch-work with 12-inch bricks and fine
lime mortar @ 11 1 7 per 100 cubic feet.

Inferior Lime Plaster, -- -- -- @ 1 2 7

Superior Lime Plaster, -- -- -- @ 1 9 4 per 100 superficial feet.

8.—*Earthern Walling*, @ 0-8-0 per 100 cubic feet, or at 5 annas per 100, if water is close at hand.

Excavated Earth-work, for sinking a well 5 feet in diameter, and 39 feet deep at 0-4-5¼ per 100 cubic feet.

Earth-work for Roads, six inches high @ 0-1-0 per 100 superficial feet, brought from a distance of 20 feet.

Earth-work for Embankments, brought from a distance of 223 feet, rammed and dressed, but without turfing. Height of embankment above 30 feet, exterior slope 94 feet, surface width 28 feet;

Rate per 1,000 cubic feet Rs. 2-4-1, or Rs. 0-3-7·3 per 100 cubic feet.

9.—I have further the pleasure of subjoining for the use of your Committee a table of the probable cost of bridges of various spans drawn up by Lieutenant D. Briggs.

Roadway 20 feet wide throughout.

Arches.	Span.	Height.	Masonry.	Probable Cost.
	Feet.	*Feet.*	*Cubic feet.*	*Rs. A. P.*
1	2	2	316	36 2 8
1	4	2	618	72 3 7
1	4	4	661	77 1 3
1	6	3	558	63 9 8
1	6	4	439	78 6 5
1	8	2½	775	90 0 5
1	8	5	1562	178 10 10

Arches.	Span.	Height.	Masonry.	Probable Cost.
	Feet.	*Feet.*	*Cubic feet.*	*Rs. A. P.*
1	10	5	1184	142 7 1
1	10	6	2288	261 14 3
1	12	5½	1830	204 1 6
1	12	8	2750	314 15 1
1	15	8	2807	309 7 10
1	15	10	4785	546 2 5
1	18	9	3659	401 7 9
1	18	9	4802	540 14 0
1	24	12	5942	690 10 8
1	24	12	8181	922 11 6
1	30	16	8827	1175 8 5
1	35	22	15176	2007 3 7

10.—The above abstract was made after Lieutenant Briggs had begun to work upon my very economical principle of an Elliptical Tunnel* lying almost without any foundation upon very bad soil, but with its floor sunk a foot or more below the bed of the watercourse, to guard against undermining by the current; which was further provided for by drop-curtains of masonry, such as would be called front and rear deep foundations in bridges of the ordinary construction.

11.—The following is an abstract of Lieutenant Briggs' estimate for bridges of the common kind.

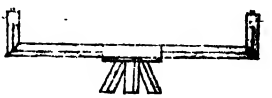
Arches.	Span.	Height.	Masonry.	Probable Cost.
	Feet.	*Feet.*	*Cubic feet.*	*Rs. A. P.*
1	4	3	960	105 0 0
1	6	5	1792	196 0 0
1	6	7	2738	296 0 0
1	8	6	3261	352 0 0
1	8	7	5265	563 0 0
1	10	7	6037	640 0 0
1	12	8	8708	932 0 0
1	15	9	10187	1158 0 0
1	20	10	13608	1472 0 0
1	20	14	18272	1973 0 0
1	25	15	18357	1987 0 0
1	30	23	30113	3255 0 0
1	31	20	31031	3356 0 0

The tunnels in each of the above being 24 feet long, the parapets 2 feet thick, and roadway 20 feet wide.

12.—I now purpose making a few general observations which may be of use to your Committee, as connected with road-making and bridge-building. The question of a levelling instrument has already been mooted in the correspondence with Major A. Knyvett, and though I think that Government would probably sell one to the Azimgurh Committee out of the Arsenal at Fort William, or from the Allahabad Magazine, (if there is one,) yet the price would probably be about Rs. 250, and a

* See page 99.

simple instrument might be made as a substitute at a tenth of that cost. A tube of brass, lead or tin, about a yard long is to be bent up about 3 inches at each end, and a couple of Eau-de-Cologne flasks or medicine phials, with their bottoms cut off, are to be cemented one into each end of the pipe (as in the marginal figure,) so that when the pipe is filled with any colored fluid about as high as the middle of the glass phial, and the whole apparatus is struck on a tripod-stand, it forms a cheap and tolerably efficient levelling instrument.



13.—Where embankment work was to be carried to a height of several feet above the plain, I have found it convenient to drive long stakes (or *bullees*) firmly into the ground in two rows, 30 feet asunder, (or whatever was to be the top-width of the intended road,) the stakes being about 50 feet asunder, and their heads exactly at the required level above the ground, so that they not only marked the alignment of the road, but showed the precise height to which the earth-work was to be raised. I also had lines cut in the ground to make the foot of the intended slope at each side, and another pair of lines to mark the width of the berm; not allowing any earth to be excavated from within those lines: in which manner the work cost fourteen annas per 1,000 cubic feet, the embankment ranging from 1 to 5 or 6 feet in height.

14.—Regarding the necessity for baling out the foundation of considerable bridges over the large streams, it may be as well to mention that in constructing the iron suspension bridge of four or five openings over the Kalee Nuddee at Khoda Gunj, between Futtehgurh and Cawnpore, my brother, Lieut.-Colonel J. T Boileau (now Superintending Engineer, North Western Provinces) diverted the current to a considerable distance by an artificial cut, and by embankments: thus raising his piers with little difficulty. An opposite plan was pursued at Indree on the Western Jumna Canal above Kurnaul, where a suspension bridge of 100 feet span was built on dry ground upon the isthmus, as it were, formed by a curved reach of the Canal; and when the bridge was finished, a cut was made under it; bringing the stream between its abutments; and the old channel was of course abandoned. Either of these plans may occasionally be found very advantageous to your Committee. And to make the Allahabad rates given in my 7th paragraph more complete, I may add that the price of well-burnt 12-inch bricks is Rs. 7½ per 1,000; of fine stone lime 8 annas per maund; of best kunkur lime Rs. 22 per 100 maunds, of common kunkur lime Rs. 11 per 100, and of soorkhee 1 anna per maund.

MEMORANDUM OF EXPERIMENTS ON, AND ANALYSIS OF, SPECIMENS OF KUNKUR, FROM ABOUT THE 393RD MILE-STONE ON THE GRAND TRUNK ROAD, NEAR NAUBUTPORE. By Lieut. C. H. Dickens, *Artillery*.

Secrole, Benares, 19th September 1849.

Two experiments were made on the hydraulic properties of the kunkur.

A., with the finer parts afterwards made into the square piece of cement.

B., with the coarser part afterwards made into the triangular pyramid.

Both these were heated, nearly to whiteness, in crucibles for an hour, and then weighed; heated again for half an hour and again weighed; and after a third heating, having found no further loss of weight, the carbonic acid and water were concluded to have been completely expelled.

A. lost 31·5 per cent. *B.* lost 28·2 per cent.

In slaking, both swelled much, cracked, and gave out a good deal of heat. They were each made up (without any addition or grinding) into a stiffish mortar, formed into the shape above indicated, and immediately placed under water.

Examined, as follows:—

After	*A.*	*B.*
6 hours, -- -- --	Not examined, -- -- --	Had set.
12 ditto, -- -- --	Had set.	
24 ditto, -- -- --	Not examined, -- -- --	Hardened, but could be marked by a strong pressure with the finger nail.
2 days, -- -- --	Could just be marked by the nail, -- -- -- -- --	Could not be marked by the nail.
3 ditto, -- -- --	Not examined, -- -- --	Grated under knife, but was not cut, to avoid spoiling specimen.
5 ditto, -- -- --	Surface very hard, and could be chipped off, after which interior cut like chalk.	
7 ditto, -- -- --	-- -- -- -- -- --	Removed, to be sent to Major Willis.
10 ditto, -- -- --	Removed, to be sent to Major Willis.	

The specimens were considered to be set, when they did not give way to the blunt point of an iron pin, diameter 60·15 inches.

The experiments were not made simultaneously, though exhibited above, as if they were so, for the sake of comparison.

The following is the result of chemical analysis:—

Carbonate of lime, -- --	40·05	
Ditto of magnesia, -- --	1·24	
Silica, -- -- -- --	1·80	
Alumina, -- -- -- --	1·75	The sand contained some alumina, probably in igneous combination with the silica.
Iron, -- -- -- --	4·75	
	49·59	
Sand, -- -- -- --	34·00	
Water, -- -- -- --	13·36	The loss,—probably in part from soluble salts, for which no examination was made.
Loss, -- -- -- -- --	3·05	
	50·41	
	100·00	

The first five ingredients are the active constituents of the mortar. Arranged in per-centage of their sum, they stand thus:—

Carbonate of lime, --	81·1	Alumina, -- -- --	3·5
Ditto magnesia, -- --	2·3	Peroxide of iron, --	9·5
Silica, -- -- --	3·6		100·0

which approaches very nearly to some of the English and French "eminently hydraulic limes."

C. H. Dickens, *Lieutenant, Artillery.*

P. S.—At the suggestion of Lieutenant Grindall, I add the method used in the analysis.

1.—One hundred grains of the kunkur, in small fragments, were placed in a glass flask, and an ounce of strong muriatic acid, diluted with an equal bulk of water, added; the flask being inclined to prevent loss by the effervescence. When the effervescence had ceased, heat was applied, and the liquor boiled for 2 hours. There remained a greyish white residue, consisting of sand and silica in minute divisions.

2.—These were separated by pouring into a vessel, 4 inches high, and giving the sand 3 minutes to settle; after which the finer particles, which remained in suspension, were decanted off. This process was repeated several times, till all the finer particles were separated. The remaining sand, by this time thoroughly washed, was dried, ignited and weighed. It amounted to 34 grains.

3.—The turbid liquid, containing the suspended silica, was poured on a filter, on which the silica remained. Washed, dried, and ignited with the filter, it weighed (allowing for the rest of the filter) 1·8 grains.

4.—The clean liquor, which had passed through the filter (including the washings,) was treated with caustic ammonia in excess, to throw down the peroxide of iron and alumina. The precipitate, separated by the filters and washed, was re-dissolved in muriatic acid, and again precipitated by carbonate of ammonia, so as to retain by the excess of carbonic acid any lime that might not have been separated by the first process. The precipitate was now washed, dried, and ignited. It gave the peroxide of iron and the alumina together 6·5 grains.

5.—The clean liquors from the two filterings (in 4) were mixed, and threw down the lime as carbonate. Excess of carbonate of ammonia was added, and when the lime had all separated, the liquor was filtered from the precipitate; which, washed, dried, and gently ignited, gave 40·05 grains of carbonate of lime.

6.—To the filtered liquor, from the above, was added phosphate of soda, which gave a slight precipitate of ammonia-phosphate of magnesia. The liquor, after standing 24 hours, was filtered; and the precipitate (washed by dilute solution of carbonate of ammonia,) dried and ignited, weighed 1·5 grains, equivalent to 1·24 carbonate of magnesia.

7.—The precipitate of paragraph 4, was re-dissolved in muriatic acid, and the iron precipitated by solution of caustic soda, which retained the alumina in solution. The precipitate carefully washed, dried and ignited, gave 4·75 peroxide of iron. The alumina was given by difference.

8.—The water was ascertained, by deducting the weight of carbonic acid, due to the lime and magnesia, from the total loss by heat.

9.—The loss on this analysis, arose chiefly from the alkaline salts not having been estimated.

GRAND TRUNK ROAD.

SELECTIONS FROM MAJOR F. ABBOTT'S REPORT OF THE GRAND TRUNK ROAD FROM GOORSAHAI GUNGE TO DELHIE.

[The following remarks are extracted from reports by Major F. Abbott, Superintending Engineer, North Western Provinces, on the state of the Grand Trunk Road, between Goorsahai Gunge (where the road branches off from the line between Cawnpore and Furruckabad,) and Dehlie. They will be found useful, as being generally applicable to roads metalled with kunkur, and passing through a level country.]

No. II.—*Extract of a letter from* MAJOR F. ABBOTT, *Superintending Engineer, North Western Provinces, to the* SECRETARY *of the Military Board, No. 3123, dated 2nd April 1844.*

GENERAL REMARKS.

29.—One of the main defects in this road, is a gross contempt of straight lines visible throughout. The road winds in every direction—the effect, doubtless, of bribery in the Native establishment: each zemeendar being naturally anxious to save his own lands. A complete reformation of this defect would cost a great deal of money, but in some places the deflections are so great that it becomes a question whether, when the present metal is worn out, it would not be better to correct the line in part, especially where the ditches and embankments of the old road require much alteration.

Lining out.

30.—The next remarkable error, is visible in the section of the Grand Trunk Road. The surface breadth, 30 feet, is much too narrow for any great line of commerce; and to add to the inconvenience and danger of so narrow a road, the causeway is raised to a height generally too great, and in many places without a shadow of necessity. The side slopes are steep, and the ditches, in many places, very formidable. The general height of the causeway it would now be difficult to lessen, without interfering with the speed of the Mail carts; but it is worth considering, whether it would not be better, on some occasions, to reduce the height of extravagant causeways, before giving an entire renewal of metal. The Executive Engineer is now engaged in taking sections, with a view to submit estimates for re-modelling the form of the road, by filling up the ditches, lengthening the slopes, &c.

Section.

31.—Many suggestions have been made for increasing the surface width of the metalled centre. I do not think that for many years to come it would be necessary to increase the breadth of the metalling. If the metal were 20 feet wide, the country hackeries would confine themselves to one track—and regarding obstructions, these can be avoided by turning for the moment on to the kutcha sides. The advantages to be derived from increased width of metal would not be commensurate with the expense.

Breadth.

32.—The insufficiency of general breadth (30 feet) is rendered more apparent by the present objectionable form of the road. The cost of increasing the width of the sideways would be considerable, and is not perhaps absolutely necessary as an immediate measure. As traffic increases, however, on this line, it will be expedient to add to the width of the road, making

* Increase of breadth.

the sideways not less than 12 feet. This may be undertaken gradually; and I recommend that in the next annual repairs, provision be made for altering the form of 20 miles of road to the section given in sheet A. *Fig. 4.* The sides should be carefully turfed, and if the advantages of this section become very evident, the improvement may be extended slowly or rapidly, according to circumstances.

33.—In the mean time, I deem it absolutely necessary to slope off the banks, and to fill up such of the ditches as are dangerous. Many of the ditches may be left to the action of natural causes, and if the strict prohibition I have given to refrain from digging any, even the smallest quantity of earth for repairs from these ditches be attended to, they will soon be filled by drift sand, and the annual debris of the causeway. In sheet A., *Figs. 1* and *2*, are exhibited the original section, and the effect of wear upon that section; in *Fig. 3* is exhibited the mode I propose as an immediate reformation. The Board will observe that there are no ditches; this is a *sine qua non.* Earth must be dug from pits not nearer than 15 feet from the foot of the slope, by which means objections are avoided, and better clay is obtained. The Executive Engineer is engaged in making an estimate for this alteration.

34.—When, however, by the elevation of the causeway, the construction of long slopes would spread the base of the road over an unreasonable extent of ground, I propose to make the slope 45 degrees, and to obviate their danger by giving small parapet walls. The necessity for such elevations will occur only in passing swamps and ravines, or in approaching bridges—circumstances comparatively rare; and I fix the height of causeway, to which parapets should be first given, at 4 feet. The side slopes will be formed of moulded clay, like Pise work.

Mud walls ordered by Dr. Ranken.

35.—As a temporary expedient to secure the safety of travellers, Dr. Ranken, Post Master General, North Western Provinces, directed mud walls to be given wherever the banks were dangerous. About 23 miles of mud wall on both sides, or 11½ miles running, have been constructed, the walls being 3 feet high. This will be an expensive measure to continue. The cost averages at the rate of Rs. 250 per mile, and the wall being perched upon the soft edge of a steep bank is liable to be washed away by every heavy shower.

Grass, on the slopes.

36.—Some attempts are made to encourage the growth of grass on the side slopes of the road, but with the stiff slopes generally prevalent, it is a hopeless task. The *Dhoob*, when planted at the edges, takes pretty readily in most places, but the sides are too much disturbed by showers, which gutter them; and the grass soon fails under the parching influence of the sun. When the slopes shall be flattened, we may perhaps get the grass to thrive; but in the mean time, I think, that it is unadvisable to incur any great expense in attempting to turf them. There is a plant called "*Akwa*," which takes spontaneously to the gentle slopes in many places: it protects the sides, and might be encouraged in other places.

Berms.

37.—Berms have been recommended as auxiliaries to roads. By "berms" I mean spaces left between the causeways and ditch; but I think this is an extravagant mode of applying space: it takes away a vast quantity of land from cultivation. Thus, a 30 feet road, 2 feet raised, with slopes of 4 inches to 1 inch, covers a space of 46 feet; add 2 berms of 12 feet each, and it covers a space of 70 feet. Now abolish the berms, and make the kutcha sides each 12 feet, which will afford good road on each side of the metal,

and the road will spread over a breadth of 56 feet. It is a mistake to suppose that hackeries will take the kutcha road whenever they are able. None but the lightest carts going short journeys do so. The heavy and long stage hackeries almost always take the metal, because upon it they can make double marches. Drivers, whose carts used to travel 5 koss a day upon kutcha roads, think 10 koss a fair day's work upon the metal. Most of the bullocks, which now travel the long stages, are shod. The expense in doing so is trifling, and the cattle work well upon the kunkur. The long stage hackeries are now beginning to bind their wheels with iron tires.

Metal, form of.

38.—The breadth of the metalling is 16 feet. Throughout the section of the metalling has been raised. In the first metalling of the road, Lieutenant Hill gave a rise of 7 inches in the centre, which gave it a most inconveniently rounded back, and when the metal began to wear, it assumed the very uncouth and inconvenient figures shewn in sheet B. This error has been since avoided; but the section may be kept still more flat with advantage. I would not allow a greater rise in the centre than 2 inches, and this should be effected by actual increase of thickness, and not by moulding the clay bed beneath into a convex form, as is generally practised.

Metal, thickness and method of laying.

39.—According to the account of the native establishment, the earlier portions of the metal were laid with kunkur 9 inches deep at centre, and 6 inches at sides. The whole thickness was laid at once without any sorting of the pieces, and was rammed to hardness by the convicts. Since the rains of 1840, Mr. Sub-Conductor Wood assures me, Lieutenant Hill's order was to lay only 6 inches throughout the breadth, and ram it (according to Mr. Wood) to 3 inches, which is impossible. Mr. Wood further states, that Lieutenant Hill allowed only 16 beds of kunkur per mile, each bed containing, per calculation, 2,400 cubic feet of kunkur, *i. e*, 38,400 cubic feet of kunkur; this, if distributed evenly over the surface of a mile of road 16 feet broad, would give a depth of only $\frac{5}{16}$th inches of loose kunkur, which would beat down certainly to 4 inches. This is much too thin, and such a metal requires absolutely a foundation, or when half worn, it is unable to support the weight of large carts, and sinks bodily into the clay beneath. This effect I have witnessed in many places, and have ascertained the point by opening out sections of the metal.

Again, with regard to laying the metal 9 inches loose, I feel assured that such a mass cannot be sufficiently consolidated by any means now in operation. I held this opinion in opposition to most of the Europeans employed in the provinces, and I found it to be perfectly corroborated by an inspection of the new metalling of the Gungeree Bridge causeway, which has been laid 9 inches thick (loose kunkur) and rammed by convicts under the eye of Sergeant Brine. No pains were spared, and in opening that portion, which the overseer considered the best and most indurated, we found the upper portion about $2\frac{1}{2}$ inches very hard and good, but all below that, loose and unsatisfactory.

Kunkur, mode of laying.

40.—The plan of laying all the kunkur without sorting, can only be admissible where the material happens to be supplied of a pretty even size; but on the lower parts, especially below Bhoegaon, this precaution having been disregarded, the metal is exceedingly rough in many places, presenting large lumps upon the surface, which must be very dangerous to cattle. The same fault is observable on the roads around Meerut.

41.—Without using the minute sub-divisions into four classes of size, as adopted on the Trunk Road in the Central Provinces, I feel assured that where 9 inches of kunkur (loose) is the standard, it would be better to lay it in two layers; the lower layer of 5 inches, consisting of the larger pieces: the upper of 4 inches of the smaller. The kunkur should be clean, but all attempts to smooth the surface by rubbing in powdered bujree, &c. should be avoided. I prefer seeing the grain of a well made kunkur road, and I always suspect a very smooth surface. The labor of this polishing is all wasted, as the powdered surface, after being pasted on, quickly wears off again in the shape of dust.

Kunkur, 2 layers.

42.—Whilst upon the subject, I would beg to observe that our Indian roads, upon which traffic of any great amount is carried, ought to have a solid foundation below the metal. Raised as our roads generally are above the level of the country, the metal resting upon the artificial mounds, it stands to reason that, where the metal is half worn, the remaining part, unable to bear the weight, occasionally imposed, sinks into the clay below, breaking and crumbling the parts adjacent. In repairing these holes the clay is again disturbed, and again the same mischief recurs. I would therefore propose, for all new and great lines, that a substratum, or foundation, of 9 inches of coarse and mixed kunkur be laid and well consolidated, and that above this the wearing metal be laid of a sufficient body to beat down to 3 inches, and that it be a standing rule, never to allow the substratum to be disturbed, but by exerting proper vigilance always to repair or renew the ruts before the *wearing* stratum shall be cut through. This will cause a greater outlay at first, but it will be attended with compensating advantages, and if the course of improvement in travelling and increase in traffic fulfils the present promise, some such system of affording stable roads *must* ere long be resorted to.

Metal foundation necessary.

43.—Expedients have been suggested to keep the country carts from following one particular track, by which the metal is unfairly worn. Every attempt has hitherto failed, and I believe that no plan can succeed. It is inherent in the nature of bullocks to follow the lead, and to keep to any marked path. On considering the subject with much attention, I feel disposed to think that this mode of wear is the most advantageous that could be used. Whether the kunkur has been well sorted, the ruts wear quite *smooth*, and become a sort of railway for the wheels; all the rest of the surface remains comparatively untouched, and when these ruts grow deep, their repair is very simple, and may be executed without impeding the transit of carriages. Small trenches, 24 inches wide, and *clean cut*, are excavated along the ruts, and then filled with new kunkur, which is beat down to the surface level of the rest of the road. On some occasions, attempts have been made, when repairing ruts, to divert the hackery wheels to other parts of the metal, by raising the new metal above the general surface level. This must be avoided; such repair makes a road mis-shapen and awkward to travel upon, and becomes much more difficult to repair. All account of centre is lost, and the state of the metal can only be ascertained by probing.

Kunkur, wear of; and repairs of ruts.

44.—The present mode of renewing metal is to take up all the old kunkur, and lay down a fresh stratum 4 inches thick, which beats down to something less than 3 inches. The system I deem to be utterly devoid of any recommendation, and I did not believe that such had been adopted until I received assurance of it in Lieutenant Atkinson's letter, No. 269, of the 19th December. That it is not a cheap plan, is evident from the experiment quoted in paragraph 47, and it is impossible to suppose that 3 inches of kunkur laid

Mode of repairing metal. Renewal.

upon a surface of clay lately disturbed by the pickaxe could afford a strong and durable surface for heavy traffic. Lieutenant Hill's stratum of 6 inches I consider too thin. I would have nothing less than a mean thickness of 7 inches.

Repair of ruts.

45.—In repairing ruts, Lieutenant Atkinson states, that the trenches are filled with 8 inches of loose kunkur, which is beat down to the level of the surface. I deem this assumed thickness to be unnatural, if not impossible. The original thickness of the metal having been 6 inches beat down to 5 inches or $4\frac{1}{2}$; and then worn for three years, can never present a thickness greater than $3\frac{1}{2}$ inches or 4 inches. This I have ascertained from many sections: if, therefore, 8 inches of kunkur are to be applied and beat down to 6 inches, it will be necessary first to excavate the clay stratum 2 or $2\frac{1}{2}$ inches below the under surface of the old bed. I have directed the Overseer never to dig the trenches of ruts deeper than is absolutely necessary. The greatest thickness of metal that I found in recently filled ruts was $3\frac{3}{4}$ inches.

Cost of metalling.

46.—The cost of metalling varies on different parts of the road according to the facilities of procuring kunkur. The expense has been considered high, and I have caused the Executive Engineer to consider the subject seriously, with a view to a reduction of rates. The price of kunkur at first starting was enormously high, not less than Rs. 3-8-0 per 100 cubic feet, and this upon a line running for the most part *over* beds of kunkur. An immense quantity of material appears to have been collected, at a time when the fair rates of material had not been ascertained; so that when Lieutenant Pott, the present Executive Engineer, took charge, he found himself burthened with 22,46,372 cubic feet of material at the above high rate. Last year, however, a great reduction appeared in this article, the Executive Engineer having succeeded in obtaining it generally at Rs. 1-8-0 per 100 cubic feet at the quarries; so that a great reduction of charges may henceforth be looked to, when the old stock of kunkur shall have been expended. There is about 10,60,000 cubic feet of it left, valued at 37,100 rupees. This quantity would be expended in 24 miles of renewal.

47.—In August 1843, Lieutenant Atkinson, then acting for Lieutenant Pott, carried out by my direction an experiment professedly superintended by himself, but as he did not remain constantly on the spot, I do not place much value in the results, which were as follows:

For one mile of metalling 16 feet broad. (The portion of road experimented on, was a fractional part; but I have reduced the rates to a full mile.)

7,559 bildars and coolies, -- -- -- -- --	676	6	0
Et cœteras, -- -- -- -- -- -- -- --	25	9	0
28,160 cubic feet kunkur, -- -- -- -- --	995	9	0
	1,687	8	0

It will be observed by this statement, that the quantity of kunkur is only sufficient to give a stratum (loose) of 4 inches, which would ram down to 3 inches. I cannot place dependence on the experiment, especially as it differs in so extraordinary a degree from one made by Lieutenant Sharp, near Allahabad, and superintended from first to last by himself, the result of which, when reduced to the standard of a 16-inches road, will be 3,120 bildars and coolies; costing Rs. 412, together with 46,666 cubic feet of kunkur, costing 1,230 rupees. Lieutenant Sharp's statement shows very nearly the exact quantity of metal due to a mean thickness of 7 inches,

yet he had this quantity beat down in four separate courses, by half the number of men employed by Lieutenant Atkinson in beating a little more than half the quantity of metal in one stratum. We cannot hope in ordinary routine to attain to so great a reduction in labor as Lieutenant Sharp did by his personal and unceasing superintendence; but allowing 25 per cent. for inferior superintendence, and we have 3,900 bildars and coolies, costing Rs. 515, and this amount should not, I think, be exceeded on the Grand Trunk Road.

48.—From examination of the accounts of Overseer O'Conner, who appears to have been one of the first who reduced in a material degree the price of kunkur, I find that this material may be quarried at the rate of Rs. 1-8-0 per 100 cubic feet; and from Mr. Conductor Wood's account, I learn that it can be carted at the rate of 12 annas per mile, which I assume as the mean distance for our portion of the Grand Trunk Road.

When therefore the old stock of kunkur shall be exhausted, we may expect the following rate: allowing a full quantity of kunkur for a loose stratum, the mean depth of 7 inches

Labor, -- -- -- -- -- -- -- -- --	515	0	0
49,280 cubic feet of kunkur at 1-8-0, -- -- --	739	0	0
Mean carriage of ditto at 12 as. -- -- -- --	369	0	0
	1,623	0	0

This does not appear a great reduction, but it must be remembered that it gives a stratum of metal nearly twice as thick as that of Lieutenant Atkinson's experiment.

Cost of maintaining Trunk Road.

49.—In regard to the lasting qualities of the metal, and therefore the expense of maintaining the Grand Trunk Road, I paid particular attention to the state of the metal on the whole line. It was however very difficult to draw an absolute conclusion from the experiments made, as the road had been constructed at various periods and in several modes, partly also by convicts, and partly by hired laborers. From careful inspection by many sections taken along the course of the road, it appears that very good metal laid down at 6 inches (the loose stratum) lasts 3 years with petty repairs. Between the third and fourth year the ruts require an entire renewal. That is, two trenches of metal 2 feet broad each, require to be filled and beaten down. This is exactly equal to one quarter of the whole metal. It is difficult, if not impossible, to calculate with any accuracy the durability of the remaining portion. In some parts I found the metal laid in 1839-40 at 6 inches (the loose stratum) presenting a thickness of 4 inches at centre, and 4½ inches at sides, showing the wear to be *nil*; at other places, I found metal laid in the same year to be altogether, or very nearly, worn out. The most ordinary result of my sections were for metal laid in 1839-40, 3 inches in centre, and sides 3½ inches, and I think we may safely assume that besides the renewal of ruts after the third year, the whole mass will require renewal in the sixth year, or repairs by degrees to that amount.

50.—The earth-work of the road also requires considerable repairs. Clay exposed to continual attrition turns to the finest powder, which is taken up by the winds, especially the gales of the vernal equinox, and in this way is found to part with a stratum about 4 inches in thickness. Again from the faulty construction of the section, having steep banks, and deep ditches, a considerable portion of the causeway is carried into the ditch by rain-water gutters, extending right across the kutcha sides,

and sometimes invading the metal itself. A reference to two years' annual repairs, shows the average expenditure on the earth-work to have been 66 rupees per mile per annum.

51.—The original cost of the Grand Trunk Road in these Provinces I have found it impossible to ascertain; the work having been performed by convicts, by the starving poor, and by regular hired labor, and under various officers. I shall therefore confine this enquiry to the probable cost of maintaining the line.

52.—One renewal of ruts after three years, with one total renewal after six years, are the same as one and a quarter total renewal in six years. By my calculation in paragraph 48, the cost of one mile of metal, when we use new kunkur will be 1,613 rupees. The expense of one year's repairs will be

$$\frac{1{,}613+403}{6} = 336 \text{ rupees;}$$

add to this the cost of earthen repairs as per paragraph 50, and we have the annual repair per mile equal to 402 rupees. This is independent of the cost of monthly repairs, establishment, &c. &c. Now, from examination of 12 months' current bills, (viz., from 1st May 1842 to 1st May 1843,) it appears that the average current expense is 97 rupees per mile per annum, inclusive of European and native establishment, as per Appendix C. Therefore, the total annual expense of maintaining the Trunk Road may be assumed at 499 per mile, or in round numbers, 500 rupees.

53.—On referring to the items in Appendix C. it will be seen that the European establishment amounts to nearly one-half the cost of the monthly repairs. In the course of time, the whole line of road will probably be placed under the Executive Officers of the several Divisions through which it passes, when a deduction may be made for the salary of the Officer, which in my estimate amounts to about 20 per mile per annum.

54.—In corroboration of my estimate, regarding the extent of repair and renewal, I will observe that the average of the bills for annual repairs of 1842 and 1843 (the only two that have been regularly submitted) is Co.'s Rs. 332, my estimate (paragraph 52) is Rs. 402; but it must be considered the fifth and sixth years have yet to run on the greatest portion of the roads; and these years may naturally be expected to give an increased amount of repairs; and I think the coincidence is sufficiently close to justify my assumption.

Bridges.

55.—The whole line of the Grand Trunk Road, between Goorsahaigunge and Ghazeeabad is complete in bridges. From Ghazeeabad to Dehlie, the unfinished bridge of 400 feet waterway on the Hindun occurs. From Hindun to the left bank of the Jumna at Selumpore the road is fully bridged. Then occurs the bed of the Jumna, requiring two small bridges, and one large one, of boats, to complete the communication with Dehlie. Between Goorsahaigunge and Ghazeeabad is a distance of 180 miles. There are 317 bridges and drains, with a total waterway of 1,155 feet, or about 10 feet of waterway per mile. There are one bridge of 20 feet, one of 14 feet, and 2 of 12 feet, span; all the rest are less than 10 feet. This is attributable to the line of road running in a parallel with the general drainage of the Doab. The total cost of these bridges is Rs. 28,786-3-7, or about Rs. 160 per mile.

56.—One great mistake, arising from false economy, is visible in the construction of many of these bridges. They are narrower than the road; the latter being 30 feet broad. There are two bridges 16 feet broad; three of 20 feet, forty-three

of 21 feet, and twenty-seven of 26 feet; the rest are 28 feet broad. Some of the narrowest are very dangerous, and they must, I think, be eventually removed. All were built originally without parapets, but this omission is in the course of rectification; indeed the whole of the parapets must be nearly completed by this time. The masonry of some of the old bridges built by contract is of the worst description; that of the later ones is generally good; but traces of unpractised hands are visible in the voussors of many of the ditches.

57.—Besides the above-mentioned, there is the suspension bridge on the Hindun not yet finished; 14 small bridges are complete between the Hindun and left bank of the Jumna; and the Jumna itself remains to be considered as to a permanent mode of communication.

58.—In order to facilitate reference, I have directed the Executive Engineer to mark in large figures the number of each bridge commencing at Goorsahaigunge.

Experimental groves.

59.—The Military Board in their Secretary's letter No. 7750, dated 14th April 1842, called for an estimate for planting groves of trees along the line of the Grand Trunk Road. On 14th August 1813, I forwarded under cover of my letter No. 1157, Lieutenant Atkinson's estimate, amounting to Co.'s Rs. 6,114-9-4. This estimate professed to be based on the actual experiment of 10 groves. These groves I visited on my tour; they are at the following places:—

Keeria,	Goolooea,
Sooltangunge,	Nubbeegunge Seraie,
Bheogaon,	Chibramow,
Bewar, (Bungalow,)	Sikunderpoor.
Ruttunpoor,	Goorsahaigunge.

These gardens differ much in size, and contain from 50 to 100 trees; a ditch and bank enclose the area. The bank is planted generally with *Sissoo* and *Peepul*, which love that style of soil. The areas are planted chiefly with mangoes, set 35 feet apart. The average of planting and forming the garden has been Rs. 20-8-5 per garden; and the expense of each garden, is 3 rupees per mensem, which expense must be continued for five years certainty. Although Lieutenant Atkinson assumes only four years, each grove at five years old will have cost about 200 rupees; and if then they be capable of thriving without further assistance, this amount will not be considered great, considering the utility of the undertaking, and the eclât that such works always give to a Government.

Proposed improvements in groves.

60.—I should wish to introduce a little change in the system of managing these plantations. At present the native plan is followed: equal distances are marked off, and to provide against too probable loss of some of the young plants, three or four are set together in the same *houze*. The evil of this system becomes evident when the trees grow up: for then these trees being unable to find nourishment in the space due to one, each tree becomes stunted. I proposed therefore to the Executive Engineer to set the plants singly, and to provide against death by increasing the number of the young plants setting one in the centre of each square quincunx fashion. These, when they have attained a riper age, may be thinned and planted out in new places, or at chowkees or other particular spots on the road side, or they may be given to zemeendars. The existing plants are generally healthy, though at "Goolovia" they appear to be neglected.

61.—I would also recommend a greater variety of plant. Many of the gardens contain in the area nothing but mangoes. A little attention to the natural foliage

of the country would enable us to produce beautiful effects. Tamarinds should be more encouraged, as well as the *Burgut* and *Peepul*.

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63.—I beg strongly to recommend a continuation of this system, making, as proposed in the estimate before alluded to, one grove at every five miles. The traffic on this road is increasing very fast. The number of travellers along it is enormously multiplying, and these last cannot fail to observe the benevolence of Government in such works, and to spread abroad the fame thereof.

64.—It has been supposed impossible to get up avenues of trees along the Trunk Road. A proposal I made to plant trees in this manner was rejected by the Military Board, in the Secretary's letter No. 7750, dated 14th April 1812. I have however since witnessed very successful attempts made by Road Committees on the road from Allygurh towards Hatrass, from Bareilly to Shajehanpoor, and from Bareilly towards Peelecbheet. The matter requires only a little care and expense. In many places the native residents would plant if encouragement were given them, and when the groves are planted at each five miles, I do not despair of seeing them connected by planting out the surplus plants along the road side.

Mile-stones.

65.—The measurement of the Grand Trunk Road has not yet reached my division. This argues some mismanagement in the lower district. It is a matter that should be set at rest, as our distances are very vaguely defined. Many of the mile-stones of the old road are still in existence. Most of them have been brought to the side of the Grand Trunk, and there set up at a guess. In Mr. Secretary Hamilton's letter No. 3488, dated 29th July 1843, the Lieutenant-Governor was pleased to sanction a pattern of mile-stone and obelisk for the roads of the North Western Provinces. But the Trunk Road is one requiring a peculiar style of mile-stone, the pattern of which should be fixed by the Board, so that all may be alike from Calcutta to the future terminus. I annex a sketch of one that I should propose. The stone to be rather heavy and fixed in masonry well clear of the road side. The distance from Calcutta should alone be marked. The distances of intermediate towns will be marked on separate mile-stones by Local Committees. The Board should also decide on which side of the road the Calcutta mile-stone should be erected, so that uniformity may be observed throughout.

Extract from the same Officer's Report to the Military Board, No. 25, dated 3rd May 1845.

General Remarks.

21.—In my former report, I suggested the propriety of correcting the curves of the line when it became necessary to renew the metal. Upon more mature consideration, I think it better to retain the old line, excepting in certain places, where (as at Coel) very exaggerated loops may be cut off at little cost. By the mode we propose to adopt in renewing metal, very little of the old metal will be actually dug up, and, by retaining the old line, we shall avoid the great expense of a new one, as well as the inconveniences of a *fresh* causeway under the metal.

Lining out.

Section.

22.—The same reasons, nearly, lead me to give up my first intention of reducing the height of the causeway, with exception to one or two very exaggerated parts; and besides, the inconveniences of disturbing the subsoil, the annoyance to traffic caused by shutting off long portions of the road would be extreme. The new system of sloping also has materially corrected the evils of high causeways, and the heights of existing bridges are so many obstacles to improvement, that I cannot contemplate the expense of renewing those structures to conform them to the reduced height of the causeway. One or two dangerous places, will, however, be reduced in the progress of renewal.

Side slopes.

23.—Agreeably to the recommendation contained in the 33d paragraph of my last report, the greater portion of the slopes have, with the sanction of the Military Board, been corrected to four of base to one of height, and many objectionable holes and ditches have been filled in. The improvement wrought by this simple and comparatively inexpensive alteration, is remarkable, and would scarcely be credited. Indeed, I do not hesitate to say that the traveller who had seen the dangerous section of last year, would find difficulty in believing himself to be upon the same road. Scarcely any wall work has been found necessary, and Lieutenant Becher thinks that, generally speaking, it will be cheaper to carry out the full slope than to give walls. Some little difference of opinion occurs on this head; but I have sanctioned his making the experiment with some exaggerated causeways, as the wall is certainly an ugly thing, and detracts from the general breadth of the road. I trust also, that by Lieutenant Becher's good management, the annual expense of keeping up these improved slopes will not be greater than hitherto. Indeed, when the turf and *Akwa* shall have fully taken root, the expense of side repairs will be greatly reduced. I wish the Military Board could see the improved section.

Increased breadth.

24.—Government have been pleased to sanction the important experiment of widening out the road to 40 feet. A small piece on this principle had been laid off for my inspection, and I may be permitted to observe that, if the whole be carried out, the Grand Trunk Road will be a noble monument worthy of a great Government. The Military Board expressed surprise at the assertion made in the 37th parapraph of my last report, viz., that almost all loaded hackeries take to the metal, and that none but light hackeries, going short journeys, prefer the kutcha sides. This opinion is daily confirmed. Lieutenant Becher and I took some trouble to observe the state of the question as we walked up the road, and I may fairly assert, that for one hackery on the earthen side, we found twenty upon the metal. It is perhaps wrong to say that heavy carts *never* go on the sides; they do so at times as a rest to the bullocks' feet; they will go three-fourths of the journey on the metal, and the remainder on the kutcha side. This applies to unshod bullocks: those that have shoes keep the metal throughout. I can understand that, during the early introduction of the system, and when it was not very perfect, the cattle drivers may have objected to the metal; in many places they are forbidden on Local Committees' roads to use the metal for fear of wearing it out; and thus perhaps many travellers still think the metal is every where reserved for the "*Sahib log*," but the reservation has been loudly complained of to me by wayfarers, and I have done all in my power to get public roads thrown open unreservedly to the public. Yet, it must not be argued that, because the metal is preferred, it is useless to widen out the kutcha sides. Width of road is always necessary, for the sides are much cut up by rain, so that at certain seasons there is none left of the seven feet of kutcha side, and there is no room for carts to avoid the fast nails;

whereas with twelve feet sides, I think we shall always be able to retain a sufficient track on each side of the metal.

Mode of repair.

25.—Although I still hold to the opinion set forth in the 39th paragraph of my last report as to the expediency of giving a solid substratum to our roads, yet as the necessity of immediately assisting a very large portion of the road, appears by the above paragraph to be urgent whilst our means are limited, I have proposed to Lieutenant Becher to overlay the old metal as it stands (without touching it with the pickaxe) with a stratum that will beat down to 3 inches. By this means, we shall be able to place in security and in fine order, 100 miles of road this year; whereas, if we were to renew with a stratum 9 or 12 inches thick, we should hardly execute 50 miles. When this new stratum becomes in want of repair to great extent, I propose to cover it again with 3 inches of metal. Lieutenant Becher perfectly concurs with me in these views, and he is making arrangements accordingly. This mode was suggested by the Military Board in their Secretary's letter No. 1236, dated 21st June 1844, paragraph 11. The only exceptions will be the round-backed sections, which will not answer as substrata, and one or two violent causeways.

Advantage of single layers.

26.—There is another important advantage gained by this mode. It is that by laying a single and thin layer, this layer will be well consolidated, as no portion of it can be concealed from the eye of the Superintendent or of his Overseers. Whereas, on opening out metal 9 inches thick beaten in two separate layers, I have invariably found the lower layer to be inferior in compactness. The eye of the Overseer cannot be everywhere, and the workmen slur over the lower layer, hoping to make all right by finishing the upper one in proper form. The error thus incurred is of a very serious nature, and very few Overseers apprehend it; it is this, that when the upper layer grows thin, it sinks bodily into the lower one, which is indeed not one whit better than good clay. This is a point deserving the deep consideration of all Officers in charge of metalled roads.

Objections, fallacy of.

27.—Many very intelligent Overseers and contractors argue against this point, and contend that, unless the upper layer *binds* with the lower, it is inferior in quality and will work up, and that to secure a proper bond, the lower layer must *not* be beaten to hardness. Nothing can be a greater fallacy, as is shown in the new mode of repairing ruts. Formerly, the old metal was cut out down to the very clay; since my last report, it has been the custom to smooth out just so much of the rut as has been worn down, filling in with a thin coat of kunkur, say 2 or 2½ inches. If the kunkur be suitably sized, *i. e.*, if the pieces be not too large, this forms a perfect repair, and wears as well as the thickest stratum would.

Price of kunkur.

28.—I am very happy in being able to report a vast improvement in this item. In the early stages of the Grand Trunk Road, the price of kunkur laid down at the road side was Rs. 3-8-0 per 100 cubic feet, and a vast stock was left by Lieutenant Hill at this price. Lieutenant Pott reduced these rates considerably, and obtained kunkur at an average of Rs. 2-4-0, or Rs. 2-8-0 per 100 cubic feet at the road side. Lieutenant Becher applied himself to greater reform, and he is at present obtaining kunkur at something like Rs. 1-10-0 per 100 cubic feet at the road side. It is impossible as yet to fix the exact average, as much of the price depends upon the carriage, and this cannot be properly regulated until the map of the road is completed; and then I expect that Lieutenant Becher will complete his arrangements and reduce the price of kunkur to a minimum. The following are the rates at present contracted for in the Northern Division, where the beds are abundant, and underlying 3 feet of clay generally.

For digging and carting 1 *pymanah* of 1,200 cubic feet
or 1,000 *munds* to 1,000 feet from quarry, -- -- -- Rs. 12 0 0
Ditto ditto 1,200 feet ditto, -- „ 13 0 0
Ditto ditto 1 mile ditto, -- „ 15 0 0
Ditto ditto 1½ ditto or 1 *koss* ditto, „ 16 8 0

For distances exceeding one *koss*, the payment will be at the quarry 10 rupees 10 annas per 100 *munds* for each *koss* (of 1½ mile).

Digging kunkur.

29.—In order to reduce the rates and contracts to something like system, Lieutenant Becher has caused four experiments to be made, the means of which gave Rs. 9-0-5 for a *pymanah*, containing 1,000 *munds*, or 1,200 cubic feet; or an average of 12 annas per 100 cubic feet at the quarry, or 9 rupees per *pymanah*. This appears to me to be a rate which can hardly be reduced, and indeed one which can only be kept as a sort of standard of minimum. Some little profit must be made by contracts, or no undertakers will come forward; but by keeping the contracts up all the year round, and allowing the contractors to supply the material at their own convenience as to seasons, they can manage to derive some profit even from our minimum rates, which are calculated for hired labor, because at certain seasons, when the fields require no attention, the contractors can procure hands at rates little exceeding the price of a seer of ottah, and such is the common practice amongst the natives.

Carriage of kunkur.

30.—The next experiment made was that for the rates of carriage. Both Overseers superintended the experiment, and it was found that a two-bullock hackery, costing 8 annas per day, could travel 4,200 feet in 29 minutes, or about 1¾ mile per hour, carrying a load of 12 *munds*. It took by some experiments 15, by others 16 minutes, to load and despatch the cart. From these data, Lieutenant Becher constructs his formula for adjusting the rates of carriage:

Let x = the number of trips, working 10 hours per day at the distance a;
$2x$ = the number of journeys to and fro;
$2ax$ = the distance travelled. Then,

$\frac{2ax}{1{\cdot}75}$ = number of hours travelled; and as it takes 15 minutes to load the cart each time,

$$\frac{2ax}{1{\cdot}75} + \tfrac{1}{4}x = 10, \text{ or } 8ax + 1{\cdot}75 = 70.$$

$$x = \frac{70}{8a + 1{\cdot}75}$$ is the equation from which are deduced the following

For one mile the equation becomes $\frac{70}{9{\cdot}75} = 7\frac{1}{4}$ say 8 trips.

$1\frac{1}{2}$ „ -- -- -- -- -- $\frac{70}{13{\cdot}75} = 5$, nearly.

2 „ -- -- -- -- -- $\frac{70}{17{\cdot}75} = 4$.

3 „ -- -- -- -- -- $\frac{70}{25{\cdot}75} = 2\frac{1}{2}$

4 „ -- -- -- -- -- $\frac{70}{33{\cdot}75} = 2$ trips.

The expense is thence deduced as follows:

		M			R.	A.	P.
1	mile -- -- -- --	96 : 8 : : 100	:	0	8	4
1½	„ -- -- -- --	60 : 8 : : 100	:	0	13	4
2	„ -- -- -- --	48 : 8 : : 100	:	1	0	8
3	„ -- -- -- --	30 : 8 : : 100	:	1	10	8
4	„ -- -- -- --	24 : 8 : : 100	:	2	1	4

31.—The above will show the attention with which the subject has been treated, and the economy of the contracts made this season. It likewise shows the great importance of an accurate chart of the quarries, towards the preparation of which the Military Board have been good enough to sanction a small temporary surveying establishment. On the completion of this chart, the general average will be calculated with great accuracy.

Cost of metalling 4½ inches thick.

32.—In the 26th paragraph, I have stated our project of renewing this year with 4½ inches of loose kunkur, which will make a hard stratum of metal, about 3 inches thick. Lieutenant Becher estimates the cost as follows:

31,680 cubic feet of kunkur at 1-8-0 per 100, -- Rs.	485	0	0
Labor, -- -- -- -- -- -- -- -- -- -- --	230	0	0
Total, Rs. --	715	0	0

The kunkur is here supposed to be carried two miles. The experiment made by Lieutenant Atkinson in 1843, as mentioned in the 47th paragraph of my last report, gave a rate equal to Rs. 1,687-8-0 per mile, for a loose stratum only 4 inches thick. So that if Lieutenant Becher's rates are carried out in practice, and of this I entertain no doubt, he will have reduced the rates by more than 50 per cent., which, if we take the average renewal, including ruts at 30 miles, would effect a saving of not less than 27,000 rupees per annum, on this portion of the Grand Trunk, and which would pay the whole establishment for two years.

Cost of metalling 9 inches thick.

33.—Although our operations this year will be chiefly confined to strata of 4½ inches loose, yet in some places where the section is much disfigured, it will be necessary perhaps to dig up the old work, and although, in most of these cases, I should prefer renewing with 4½ inches of loose kunkur, as mentioned in paragraph 27, yet it is well to prepare for occasional layers of 9 inches, loose. Lieutenant Becher estimates this as follows:

63,360 cubic feet of kunkur, at 1-8-0 per 100, -- Rs.	970	0	0
Labor, -- -- -- -- -- -- -- -- -- -- --	450	0	0
Total, Rs.	1,420	0	0

This rate goes far below my best hopes of 1841, and the average cost of 9 inches metal last year was 1,800 rupees per mile; and this latter rate has been vastly reduced since my report upon the Trunk Road.

Cost of repairing ruts.

34.—Ruts are repaired by cutting clean troughs 21 inches broad and about 2½ deep. Lieutenant Becher estimates for repair of 1 mile of double ruts as follows:

6,160 new kunkur at 1-8-0, -- -- -- -- -- Rs.	95	0	0
Labor, -- -- -- -- -- -- -- -- -- -- --	90	0	0
Total, Rs.	185	0	0

Or about 40 rupees per mile less than last year's estimates, which estimates have also been much reduced.

35.—Almost all the kunkur has lately been supplied by contract, and some of the repairs of earthen sides have lately been contracted for. In the Military Board's letter, No. 6772, dated 21st February 1845, the orders of Government were communicated, to endeavour to execute the whole of the works by contract. Lieutenant Becher has therefore issued an advertisement, calling for tenders.

Contract system.

36.—The supply of kunkur, the construction of earthen causeways, the repairs of sides, and such like work, will certainly be more economically executed by contract; indeed, these have generally been contracted for. The great trial will be in laying down the metal. At present, the natives appear to be afraid of undertaking the contract, knowing the requisition of the department in regard to the quality of work. They are also generally in utter ignorance of the approximate rates. Some whom we sounded on the road side, men who had been contracting for the supply of kunkur, asked more than our own working rates. Others, Lieutenant Becher informs me, are coming forward, saying, "What are your rates? Give us Rs. 50 less per mile." It is to be hoped that some Europeans of respectable character may come forward, but even in this case the utmost vigilance will be required; for, if the European contractor undertakes more than he can personally superintend, and if he cannot afford to place European assistants under him, he will be deceived in the work. In either case, it will be absolutely necessary to increase the number of Overseers on the Grand Trunk Road between Dehlie and Goorsahaigunge. I have lately had cause to condemn a great quantity of metalled road made for the Boolundshuhur committee by an European contractor of great respectability, Mr. Greig.

37.—I cannot pretend to say what reduction the contract system will make in the rates of metalling; but Lieutenant Becher will do all in his power to introduce it, at least upon trial, as he is most anxious to free himself from the labor of accounts, which at present occupy much of his and the Overseer's time, and render their personal superintendence less efficient.

38.—The main portions of the bridges are in good order. All have parapets, but I regretted to observe some very bad masonry in the parapets of the Southern Division, the cement being of the worst kind. The materials of the parapets in the Northern Division were better, but in some cases the walls were giving way at the wings for want of proper foundation. The Overseers complain that the size of their divisions, 90 miles each, prevents their seeing every thing properly executed. No attempt had been made before Lieutenant Becher joined, to number the bridges. The work was only half advanced during my inspection. It must now be finished, and it will afford great facility in keeping a register of the condition of the road, for, without such land-marks, it is very difficult to make accurate notes.

Bridges.

39.—Ten groves of trees were mentioned in my last report, and four more had been formed ere the receipt of the Hon'ble the Lieutenant-Governor's prohibition. All the groves are in good and flourishing condition; the improvements recommended in my last report have been carried out. The cost of making and preserving these groves up to 1st January 1845, has been Rs. 872-6-5. The average expense of forming one grove is Rs. 32-6-0; the average annual expense of keeping it up is about Rs. 19. These are small sums, and the current expense even is calculated to cease in 5 years. The upper portion of the

Groves.

Grand Trunk is lamentably barren of foliage. Will these sums be considered inadmissible by Government with advertence to the ultimate decoration of the country and the comfort of travellers? Only one symptom of planting on the part of private munificence is visible, and this consisted of a few trees near Secundra rao.

Chowkies.

40.—An estimate for constructing 18 chowkies between Dehlie and Goorsahaigunge was transmitted on the 25th April last, amounting to Rs. 15,656-14-6. I hope that it will meet with favorable consideration, as I consider it very necessary that the officer and his assistants should have the means of moving rapidly along the road, which they cannot do if obliged to march with tents. When large works are going on, the work people always get intelligence of expected visitation, so that unless the Superintendent's movements are brisk, he cannot discover the real condition of the work.

FORMATION AND MAINTENANCE OF THE GRAND TRUNK ROAD.

No. I—*Extract of a Letter from* MAJOR P. W. WILLIS, *Engineers, Superintendent of the Grand Trunk Road, addressed to* CAPTAIN J. D. CUNNINGHAM, *Engineers, in charge of the Superintending Engineer's Office, N. W. P., Umballa, No. 1306, dated 20th December 1850.*

I will point out the principal data necessary for designing plans of works proper for a line of road, &c., such as are absolutely requisite to be registered before any correct estimate can be framed.

4.—To prepare and mature the data for the embanked road and drains, the levels of the line should be accurately taken; or, if time should not admit of taking the levels of the whole line, at least levels must be taken of all dips, hollows, rivers, nullahs and valleys, jheels, undulations of ground along the line; and the highest known flood marks should be drawn upon the sections. The number and nature of the designs for drains, depend chiefly on the knowledge of the extent and depth of the highest floods, and it is impossible to provide for the drainage of an embanked road, without levels of the natural ground.

5.—As the line is to be made really an efficient one, as a commercial and military road of communication, the greatest care should be taken to determine with accuracy, the exact amount of waterway and of raising required, and its liability to floods; so as to render the road passable at all periods of the year.

6.—I recommend your attentively considering the following points:—

1stly.—The propriety of the choice of the ground for the new road.

2ndly.—The proper height of the road in respect of the water-line at the extreme of high floods.

3rdly.—The proper quantity of waterway for the necessary passage of the water through the said road, in the time of the said floods, so as to prevent its being overtopped and breached; bearing in mind that a road should never be too little or too much raised, that it is throwing away expensive metal to spread it upon a road liable to be under water at any time; whilst at the same time care should be taken that the embanked road shall overtop the extreme height of flood by only about 1 foot, or 1½ foot; the latter in sandy soils liable to great settlement.

4thly.—Consider the particular places where arches ought to be situated, and the number and dimensions of the arches proper at each particular place.

5thly.—Consider the best method of construction and the form of the said arches, so that they may be done at as little expense as possible, consistent with their being effectual.

6thly.—Carefully consider the proper section of the road where it passes through ground liable to inundation from rivers overflowing their banks.

7thly.—Consider the nature of the metal procurable, the distance of quarries from the road; the materials generally procurable for building purposes; and the rates for carriage and laborers of all kinds.

8thly.—Carefully consider the nature of the soils on which foundations are to be posited, and the velocity of streams for which waterways are to be provided.

7.—You must bear in mind that there are two most important requisites for a road; the one is *thorough drainage*, the other is *consolidation*. The latter desideratum is not to be attained without perfect drainage. Drainage was, before my supervision, too much neglected on the Trunk Road, and it is still neglected on most of the district roads under Local Committees. To provide sufficient drainage on the first

construction of a road, would cost much less than the wear and tear occasioned by the want of it, and indeed without both evils being thoroughly provided against, no *labor or expense* will keep the road in a first-rate degree of perfection. No metalling ought to be considered as finished until thoroughly consolidated; that is to a degree that will admit of horses in draft trotting over it without much extra exertion.

8.—It was after mature consideration of the above-mentioned points, and after carefully taking the data for the designs and estimates for the work (now under construction) of the Grand Trunk prolongation between Dehlie and Kurnaul, that we were enabled to submit at once the whole of the numerous estimates and plans for earth-work, drains, bridges, and metalling, with sections or profiles of the ground and of every nuddee and its valley, &c., for that line of road. I send you a list of the maps, plans, and estimates connected with this line of road extending about 75 miles, from the Lahore gate at Dehlie to Kurnaul. I have inserted the amounts of each estimate, and the total estimated expense of every item (including large bridges) to complete the line in the most *permanent manner*. Thus I have fully answered your query as to the expense of a line of road *nearest* to your locality, though it is not quite a hundred miles as you required.

9.—The Grand Trunk between Dehlie and Kurnaul will be a beautiful line of road, almost straight as an arrow, except were a slight curve of six miles is laid out on the railway principle, and not being perceptible to the eye of a traveller, is therefore of no consequence.

10.—As to the standard width of surface of the Grand Trunk Road, I beg to say it is thirty feet at surface, with side slopes of four feet of base to one of height, except when above six feet.

No. II.—*Extract of a Letter from the* Superintendent Grand Trunk Road, *addressed to the* Secretary Military Board, Calcutta, *No. 1053, dated 5th November 1850.*

12.—Now, as regards the maintenance of the road, I beg to submit the following observations, which describe and prove the efficiency of the measures adopted, and the principles which guide me, viz.

13.—There are two most important requisites for a road; the one is thorough drainage, the other is consolidation. The latter desideratum cannot be attained without perfect drainage, which latter has been too much neglected; but to remedy the defect would cost much less than the wear and tear occasioned by its existence, and indeed without both evils being thoroughly provided against, no labor or expense will keep the road in a first-rate degree of perfection. No metalling ought to be considered as finished, until thoroughly consolidated, that is, to a degree that will admit of horses in draft.

14.—The great advantage in maintaining roads in good condition, as a measure of economy, cannot be too often repeated, or too strongly enforced. A road in superior condition is assumed to be one that has always a hard and even surface with curvature just sufficient to allow the water to run off, and at no time with extensive patches of the usual sized broken metal now laid upon it.

15.—It is proved by the best practice in England and other countries, that it is good policy and economical to expend a considerable additional sum annually in improving and maintaining the road in a superior manner, if not to be effected

without such extra expense. The ordinary course of proceeding, is, to lay down metal along a road just before it arrives at its minimum thickness, and at a sacrifice of some direct increase of expense upon the road, with a view to make some improvement. But the greatest improvements may be made by a proper system at very little, if any, increased outlay.

16.—Now to prove and establish such a position; on a thoroughly consolidated road, the wear is even, gradual, and very slow. The former usual mode of proceeding, and which is still too commonly the case in some divisions of the road, was to wait until the surface had lost its shape, and then a thick covering of metal broken to the usual dimensions, was applied over extensive distances and not sufficiently consolidated. This produces heavy draught, chance of injury to horses' feet, a very slow formation and consolidation, a great deal of displacement of material, and extra grinding and wear and tear. And these portions of the road are periodically rendered almost unfit for transit, and ultimately remain a mis-shapen fixing of not half the quantity laid down.

17.—Now the most perfect system has been obtained by a constant watching, and the application of very small patches of stone broken fine, carefully supplied to the "small hollows as they shall successively be formed."

18.—It is evident that instead of all the grinding and crushing of the material, which attends the passage of wheels over a rough road, the friction and consequent wear on that which is perfectly even and hard, must be most trifling.

19.—Under the system here recommended as best, and adopted on the Trunk Road, there will be, no doubt, some additional manual labor requisite on the road; but, at the same time a most decided saving of material and in the carriage of it; and in places were the material is distant, the saving on that item will be greater than the expenditure on the other: thus obtaining an absolute deduction in outlay, to procure the perfect road, and (what is of advantage in India) increased work for the laboring population, or the substitution of manual labor for the employment of material and animals. Under this thorough good system, the better the road is, the less will be the outlay upon it. This principle requires a different manner of proceeding from that of occasional working at intervals. It will require men on constant duty for every part of each division. In England, men have been employed on this principle called "milemen," and with success. In France it is very general, if not universal; they are called "cantonniers." On the Grand Trunk Road, we call them "*nokur* coolies." Such men must reside close to the road in huts, erected at the expense of the Government. When not actually employed in patching metal, there will be ample employment for these "*nokur* coolies" in raising and trimming the kutcha sides and slopes, turfing, watering, preparing and breaking metal, &c.

20.—It will be the duty of the Overseer to regulate the work for each gang of coolies. If a road that has four inches or more thickness of broken metal upon it, is in bad condition, the proper process will be, (not that ordinarily pursued, of immediately laying three or four inches of fresh material over its surface, but) to commence clearing dirt and dust off the hollows, then to make good the surface to an even and proper shape; pick up all the little hollows and ruts, fill them with metal broken fine, and have it well watered and rammed down to the hollows.

21.—The thickness of consolidated metal need never be more than eight inches, and should never be less than four or five. When reduced to that minimum, and provided its surface be good, it should be picked to the depth of half an inch, and about four or five inches of broken metal laid upon it, and well rolled or rammed;

using artificial watering if done in dry seasons; for, without watering, no metal will consolidate. The metal should be rolled or rammed. Rolling for broken stone, gravel and khoah, is best; but kunkur metal is best consolidated by the rammer. The latter has been used with the greatest success for the kunkur in the Upper Provinces.

22.—This coating of four or five inches will be the substance for regular wear, and it is calculated, will last three years; small depressions, inequalities, or want of form, as soon as they can be perceived, being minutely corrected from time to time, by picking the surface, and then patching with small quantities of metal, broken fine, *watered*, and rammed down. Provided these principles be duly and properly carried out, the annual estimates will be required only for the provision necessary for quarrying, carriage and stocking of metal; the *nokur* coolies spreading and consolidating it.

23.—I am of opinion that this system will preclude much petty peculation and fraud, which is scarcely to be checked on the method of working at intervals on large estimates.

No. III.—*Summary of Rules for working Nokur Coolies.*

1.—The "*nokur* coolies" are a permanent establishment, for making all the petty repairs to the surface of the metalled road, kutcha sides and slopes, mud walls, turfing, and tending trees.

II.—The establishment is fixed on the following scale; which however is liable to modifications as experience may hereafter point out. One mohurrir or native accountant for every Overseer's charge, or 50 miles, at 8 rupees per month; one sirdar coolie for every 16·667 miles, at 6 rupees per month; one mate coolie for every 5·55 miles, at 4½ rupees per month; ten coolies or "milemen" in the dry seasons, and fifteen coolies in the rains, for every 5·55 miles, at 3 rupees each per mensem.

III.—These coolies are to be furnished with tools at the expense of Government.

IV.—Regular Monthly Returns of tools are to be sent to the Executive Officer's Office.

V.—When tools are worn out, they are to be submitted to a Committee of Survey, and after being condemned, the unrepairable tools are to be sold by auction, and the proceeds brought to the credit of Government, in the half yearly Cash Accounts of the Executive Officers.

VI.—When new tools are required, the Executive Officer is at liberty to get them made up, either by contract or otherwise as may be cheapest; and after being submitted to a Committee of Survey, they can be charged for in the current Expense Bills, with proper vouchers attached.

VII.—The coolies are to be furnished with huts at the expense of Government, excepting the walls, which must be built of mud by themselves, agreeably to the following dimensions; each hut is to consist of mud walls, two and a half feet thick, and eight feet high to eaves, outside; and to have gable ends at 25 degrees slope, for a tiled roof on a ridge pole. The internal measurement of each hut is to be thirty feet by ten in the clear, the rafters are to be of the commonest and cheapest kind procurable. Over the rafters a bamboo frame is to be laid to carry the tiles.

VIII.—The roofs of the coolie huts will be constructed at the expense of Government, on regular estimates submitted by Executive Officers.

IX.—The Overseers are to be held strictly responsible for the proper employment of the coolies, and are to submit to the Executive Officer, weekly reports of how they have been employed, whether on metal, earth-work, mud walls, turfing, or tending trees.

X.—The Overseer is to keep a long Roll or Descriptive Roll, of all the sirdars and mates; also an Acquittance Roll Book, with names of all employed coolies included, with their several stations noted.

XI.—The coolie huts are to be 5·55 miles apart from each other, and their positions are to be so regulated that the huts shall be in the centre of each mate coolie's charge.

XII.—The key and charge of the nearest Overseer's chowkie is to be kept by the mate coolie in charge of the nearest gang. This will obviate the necessity of hiring chowkeedars.

XIII.—Executive Officers and Overseers are to adopt the strictest measures for the supervision of the sirdars, mates, and coolies. Every sirdar and mate coolie is to be made responsible for the work of their respective gangs; and on the occurrence of the first fault or neglect they may be guilty of, their punishment should be instant dismissal, and the fact of their dismissal, with a copy of their Descriptive Roll and nature of the fault for which they were dismissed, is to be made known throughout the division and neighbouring divisions, so as to preclude their getting service under other Officers.

XIV.—The perfect development of the "*nokur* coolie" system necessitates, that the attention of sirdars, mates, and coolies should be strictly confined to their prescribed duties. Executive Officers are therefore positively forbi to employ any one of the Road Establishment for the conveyance of letters or orders, however emergent, or in any manner whatsoever, except in their prescribed duties.

XV.—Executive Officers and Overseers are empowered to collect two or more sections of coolies, for employment in any neighbouring section where urgent repairs or where the road may have sustained great damage, and instant repair may be necessary; the men being bound to return to their particular stations, as soon as the said urgent repairs have been completed.

XVI.—In reference to the above, and to the prescribed duties for the coolies, a Form of Voucher, for work actually done, is herewith annexed. This voucher is to be attached to the Monthly Current Bills in which the wages of establishment are charged.

XVII.—Every mate coolie, after lining out and measuring the day's work for his gang, or a section, will make an inspection of one-half of his charge, 5·55 miles daily; every sirdar coolie will make an inspection of his charge 16·667 miles, at least twice a week; every Overseer will make an inspection of his charge, 50 miles, once during a month; and he will record his visits on a board hung in every chowkie, shewing the dates of arrival and departure. These boards, or the paper from off them, are to be sent to the Executive Officer's office for record at the expiration of every year; besides which the Overseer is to report his inspection in the usual Monthly Report of progress.

XVIII.—Executive Officers and Overseers are to take care to instruct and see that every sirdar and mate coolie understands how to line out and measure work; and that they are duly provided with ropes and iron pickets for lining out excavations, &c., and with proper measuring rods. Every mate coolie is also to be furnished with an iron ring 1½ inches interior diameter, and he is to be instructed, that he will be liable to fine or dismissal, if he allows a piece of metal to be put upon the road, larger than can be passed through this gauge.

XIX.—As the State is put to great expense for metal for the Grand Trunk Road, it is indispensibly necessary that no metal should be laid down without its having been properly stacked, measured, and reported on, for record in the Executive Officer's office. Even for petty repairs this should be done. It may sometimes be impossible to procure a level piece of ground near the road, whereon to stack the metal in regular rectangular stacks, such as can be accurately measured; consequently, in such localities, it may be permitted to stack the metal on the kutcha side of the surface of the road; but under no other circumstances ought stacks of metal to occupy any portion of the surface—thirty feet of the road. Executive Officers and Overseers will be liable to severe animadversion, if they allow metal to be stacked on the kutcha sides, when there are other places adjoining the road, whereon it might be stacked with advantage. The whole breadth (thirty feet) of the surface of the road, must be kept open for the convenience of traffic, and it is the particular duty of Executive Officers and Overseers to see that it is so kept.

COMPARATIVE COST OF CARRIAGE ON METALLED AND UNMETALLED ROADS.

Extract of a letter of the Post Master General, North Western Provinces, to the Hon'ble the Lieutenant-Governor, dated 30th September 1850.

A calculation based on the returns of the Bullock Train, goes far to prove that without any reference to the general interests of the country, the want of a road to Lahore annually causes Government to incur an expense greater than would keep in repair, and pay interest on, the original cost of construction of a metalled road.

The following statement shews the actual number and weight of packages conveyed from Allahabad to Cawnpore, and from Meerut to Umballah, in the month of May 1850, together with the cost of establishment on each road. I have selected May as a month in which the establishment was fully employed, and one during which there are no difficulties arising from rain.

	Miles.	*Number of Packages.*	*Gross Weight.*	*Cost of Conveyance.*
			Mds. Srs. C.	Rs. A. P.
From Allahabad to Cawnpore, --	125	3,591	6,002 26 9	1,748 0 0
From Meerut to Umballah, --	128	1,992	2,929 1 0	2,632 10 8

The distances are nearly equal to each other, and to the distance between Kurnaul and Loodiana; so that the comparison can be at once applied to the latter line.

The result is, that the actual cost of conveying and guarding one ton of goods on the metalled road is Rs. 8-2-1, while on the unmetalled road the cost for the same distance is Rs. 25-2-6. From these data it is easy to estimate the cost of leaving the road in its present state. The sums mentioned merely shew the actual charge of haulage in dry weather, and do not include the cost, and wear and tear of carts and waggons, or any estimate of the loss occasioned by the unmetalled road by delay caused by rain.

Rs. A. P.
0 1 0½ per ton per mile.

Rs. A. P.
0 3 1½ per ton per mile.

If the Markundah river be left out of consideration as impracticable, there is no engineering difficulty on any part of the line between Kurnaul and Loodiana. The streams which intersect it are of no great width. I believe kunkur is to be found in the neighbourhood of the road, and for upwards of 40 miles it runs through the territory of the Maharajah of Puttiala.

Even if the whole were completed by the British Government, the cost could hardly exceed Rs. 5,000 a mile. At this rate, the total cost would be about six and a half lacs of rupees. The annual cost of keeping a metalled road in repair is, I believe, about Rs. 300 a mile; all establishments included. The total annual charge on the road in question may therefore be reckoned at Rs. 70,900.

Interest on 6,50,000 at 5 per cent.,	32,500	0	0
Annual repairs of 128 miles at Rs. 300 per mile,	38,400	0	0
	70,900	0	0

The difference in the cost of the conveyance of each ton of goods would be as above Rs. 17-0-5.

Charge for conveying one ton on unmetalled road,----------	25	2	6
Charge for conveyance of one ton on metalled road,----------	8	2	1
Difference,	17	0	5

If therefore the weight of goods, for the cost of conveying which Government is charged, amounts in the year to 4,164 tons, the whole cost of making and keeping the road in repair would be covered.

I have no means of knowing the weight which actually passes between the Provinces and Loodiana, *en route* to the Punjab, the Jullunder Dooab and Ferozepore; but if Ordnance and Commissariat stores, baggage of troops, and miscellaneous articles for Civil Establishments, are taken into account, I conceive that on the average of years, the amount would not fall short of that indicated above.

To this must be added many advantages, the money value of which cannot be shewn; such as increased speed and regularity of the mails; the absence of all obstructions to the movement of troops; and the avoidance of the thousand annoyances, delays and injuries which are now caused by a shower of rain.

It is needless to dwell on the injury to the traffic and general interests of the country by a state of things which triples the cost of carriage, and for four months in each year practically closes all communication above Kurnaul and Seharunpore.

On the Trunk Road, a pair of bullocks can with ease drag a ton of goods. Even if, therefore, a toll of 5 rupees was imposed on each cart drawn by two bullocks, the merchant and public would gain 12 rupees in each ton of goods passing between Kurnaul and Loodiana.

TRAM ROAD AT AGRA.

MR. REID'S *Report on Tram Road at Agra, dated 15th December 1846.*

The Government Order of the 3rd June 1846, received with the Commissioner's letter of the 9th idem, No. 324, desires information on two points, viz., the expense and efficiency of the Tram Road already constructed, and the cost at which such a road can be constructed.

The length of the road already trammed, or from near the eastern gate of Government House, through the Loha-kee-mundee to the great Civil Line road opposite Moozuffer Khan's Bagh, is 6,250 running feet, or about one mile and one-sixth. The width is 5 feet, *i. e.*, 3 feet between the trams and 2 feet for the stones, each stone or tram being 1 foot. The stones are laid on a foundation of brick and mortar, 9 inches thick, so as to prevent their sinking under heavy pressure. The spaces between the stones and the berms, or side supports, are filled up with broken brick and earth, well rammed down, with an upper coating of kunkur. Under the seams, or where two stones meet, sleepers (or transverse stones) are introduced, for some part of the way.

The expense of the construction aggregates Rs. 2,568, (or per mile 2,200 rupees,) exclusive of the value of convict labor and cost of kunkur, which may be safely reckoned at 1,000 rupees, (I have no means of ascertaining particulars,) making a total of Rs. 3,568.

A further sum of Rs. 705-11-6 was, under Government sanction of 3rd June last, laid out in drains, and in compensating parties for houses pulled down, in order to obtain greater width of road, and a direct line; but this ought not to be taken as an item of road-making.

As an experiment, I believe, this Tram Road has met the object of its construction, viz., to make permanently easy, the passage of heavily laden carts over an originally heavy and tortuous thoroughfare. The Garreewans, who ought to be the best judges, and to whom I have often put the question, bear testimony to the fact, and their only regret seems to be, that the tram has not been taken up to the Custom House,* where they unload their carts.

Up to the present time, the road has, notwithstanding constant travelling on it by day and by night, stood very well with occasional repair wherever the centre and sides of the stone were cut up by wheels going off the tram. During the day, or when the drivers can see the track, carts seldom or never go off the stone, but at night when the stone cannot be distinguished, this sometimes occurs, and ruts are formed. The only preventive to this kind of straggling would be a stone or iron parapet or rail, about 6 inches high on the sides of the tram, but this again is objectionable in some respects; for instance, if in a train of salt or cotton carts, a front cart break down, it would be difficult to remove it, to admit of the others progressing; or, when carts travelling counter-ways, come in contact with each other, there would be a dead halt and much loss of time. At present, whenever any obstruction occurs, the carts go easily off the tram, and fall back on it when the way is clear. Until we can afford to have a double track, or to separate parallel trams, the best plan will be to keep the sides of the single track in repair with kunkur or gravel. Ten or fifteen prisoners, continuously kept on to look after ruts, would, I think, be sufficient to maintain a mile in good order.

* A distance of 9,160 feet, or about 1½ mile.

I now come to the question of the expense at which a Tram Road *can* be constructed. By this I suppose is meant a road of some length, say 10 or 20 miles. Now, it must be remembered that the expense of the line already constructed, as given above, is not a fair criterion for other similar undertakings; because most of the stone we have used, was obtained, free of cost, from the Taj and other Nuzzool buildings near at hand. No more stone is available at these places, and therefore new stone must be procured from the Futtehpore Sicri, or Jugnair quarries. Such stone cannot be got for less than 18 rupees a hundred maunds, (taking 1 mile with another) cut into blocks of the requisite size, and thrown on the road to be trammed.

A block measuring 1 bar, or 10 feet in length, $1\frac{1}{4}$ feet in width,* and 1 foot in thickness, I find weighs $18\frac{3}{4}$ maunds; two such blocks (for both trams) would weigh $37\frac{1}{2}$ maunds, which is the quantity of stone required for every 10 feet of length. Then $37\frac{1}{2}$ maunds $\times$ 528 lengths, or 1 mile of 5,280 running feet = 19,800 maunds, which at the rate of 18 rupees per 100 maunds would cost Rs. 3,564.†

The expense of the masonry bed of foundation would be Rs. 528;—thus, 5,280 feet in length $\times$ $2\frac{1}{2}$ feet in width, and $\frac{1}{2}$ foot in thickness or depth = 6,600 cubic feet, at 8 rupees per 100 = Rs. 528.

The kunkur for the centre space and side supports would cost Rs. 480;—thus, 10 feet long $\times$ $5\frac{1}{2}$ feet wide ($3\frac{1}{2}$ feet for centre and 1 foot for either side,) and 1 foot deep = 55 cubic feet, requiring 45 maunds.‡ At this rate, a length of 5,280 feet would require 23,760 maunds (say 2,400 in round numbers) at 2 rupees per 100 maunds = rupees 480.

For earth-work, by hired laborers, implements, supervising establishment, &c., I estimate 150 rupees a mile.

On the above assumptions, the expense for every mile of road trammed, would be rupees 4,722§, viz.

For	Stone, -- -- -- -- -- -- -- -- --	3,564
„	Masonry bed, -- -- -- -- -- -- -- --	528
„	Kunkur, -- -- -- -- -- -- -- -- --	480
„	Earth-work, &c., -- -- -- -- -- -- --	150
	Rupees --	4,722

For a line from Futtehpore Sicri or Jugnair, where the stone is quarried, the expense might be somewhat reduced, supposing the road to be commenced from the quarries to Agra; but considering all things I do not think it possible to make a good Tram Road of uniform construction from end to end, at an average cost of less than 4,500 rupees.

For the work already done, it is true we got some stone from the dilapidated Futtehpore buildings at an expense of 15 rupees per 100 maunds; but the blocks were not of one thickness, or width; some were 10 inches thick, some a foot, and some only 8 inches; and consequently, the tram cannot be of the same durability throughout: the thicker stone will resist the pressure better than the rest. In future operations, I would make all the pieces of stone used, exactly of the same dimensions.

* I would have a less width for each tram at least at bottom; the surface may be 1 foot.

† This would be the cost at Agra, including quarrying and conveyance: at the quarries it would only be 6 12.

‡ This I calculate thus: for a *pymana* or measure of 9 cubic feet we allow 7 maunds of clean kunkur; then, if 9 feet give 7 maunds, 55 feet will give nearly 45 maunds.

§ This estimate is exclusive of drains, bridges, &c.

No. II.—Note by Mr. C. C. Jackson, *Magistrate and Collector of Agra.*

The advantages attending the Tram Road are great in the neighbourhood of a large city like Agra, where the ways are so contracted by houses and ravines, as to compel the carts always to follow in the same ruts; and I should on that account be glad to see the present road continued to the Custom House, a distance of 1½ mile, but the great expense attending its construction will prevent, I think, its being continued to any distance: indeed, its advantages are trifling as regards the reduction of draft in a broad and generally hard road like that to Futtehpoor Sicri where the carts can see their track; and I am of opinion that the distance might be laid down with a single line of iron rail obtained from England at less expense, for the support of which no masonry work would be required, and which would always keep the trains in their proper track. The diminution of the draft would also soon pay their expense, reduce the costs of carriage for salt and cotton, which come from the westward in large quantities to Agra, and afford an ample supply of stone from the quarries for building purposes.

No. III.—Note by Captain J. H. Oldfield, *Executive Engineer, 10th Division.*

On the general question of Tram Roads, I beg to subjoin the following memorandum from my note book.

"*Advantages of stone Tram Roads for animal draft.* Example,—Commercial Road, London. These stone, wheel tracks are recommended by Stephenson, for cities and for all acclivities of more than 1 in 26, which itself is sufficient to decrease the power of draft by one-half. On an acclivity of 1 in 5 near Glasgow, a horse, with the assistance of cast iron Tram Road, drew 3 tons in a cart weighing 9 cwt. with less difficulty than he previously drew 24 cwt. up the same ascent on a causeway. The stones recommended by Stephenson for this kind of road should be of granite, basalt or other hard stone, hammer dressed, their size 6″ to 8″ long in the direction of the track, 12″ to 14″ in depth, and 18″ wide at bottom, and 12″ at top of wheel track. The Tram Road should be laid in good concrete or marble masonry, with a good metalled horse track between the trams and on both sides of it, and even with it."

With regard to local circumstances, a Tram Road from the quarries at Futtehpoor Sicri would probably have a great effect in bringing stone building into more general usage in Agra, and might even render it an article of commerce when once cheaply brought to the river side.

STONE QUARRIES AND ROADS.

FROM F. H. ROBINSON, ESQ., *Commissioner of Agra Division, to* J. THORNTON, ESQ., *Secy. to Govt., N. W. Provinces, Judicial Dept., No. 26, dated 9th July 1845.*

SIR,

I have the honor to submit, for the consideration of His Honor the Lieut-Governor, such information as I have been able to obtain on the subject of your letter No. 4760 of 1844, together with all the correspondence that has taken place on the subject.

2.—We must set out with allowing, that the ordinary metalled roads of the country cannot bear the immense weight of the salt carts. This, experience has proved. The metalled roads are either uniformly destroyed by this traffic, or the road is preserved by excluding the traffic, and forcing it on a line parallel or nearly parallel.

3.—The accompanying map will shew at a glance the course of the traffic through my division, the different lines of commercial intercourse are marked in yellow, and the Customs line by a broad red line.

4.—The line of traffic of most importance is that from Noh in the Dehlie territory, which would at Kosee take up the large traffic between Dehlie, Muttra, and Agra; but the distance is too great for a first experiment, and there is an insuperable difficulty in procuring stone fit for a Tram Road. The rocky hills near Noh do not possess, I am given to understand, any known quarries of suitable stone, and it is evident, that wheresoever our road proceed it must begin at the quarries, and thus be enabled by the facility of carriage to, as it were, make itself.

5.—There are two sets of quarries available; one at Roopbass, in the territories of the Rajah of Bhurtpoor; the other at or near our town of Jugnere, in pergunnah Sirhinde.

6.—If the road commence from Roopbass to Agra by the chowkee of Bichpoorie, it will, besides, facilitating the commerce in stone, and considerably lowering the price of that useful article, at once become available for a great part of the commerce in sugar, salt, and cotton, now moving on the many lines converging at Bichpoorie. The commerce on customable goods, which has passed Bichpoorie, amounts to the values shown in the annexed return.

Memorandum of the trade, that has passed the Bichpoorie Chowkee, from February 1844 to February 1845.

Year.	Month.	Salt.			Sugar.			Cotton.			Remarks.
		Quantity.	Value.	Duty.	Quantity.	Value.	Duty.	Quantity.	Value.	Duty.	
1844	Feby., ...	78894	246895	157680	2754	10587	662	15263	152630	7631	In these months the trade of the Pengree Chowkee is included in the Bichpoorie statements; but it is very trifling, and consists chiefly of Cotton and Sugar.
	March,...	61799	158187	12359	6400	28800	1800	35080	350800	17540	
	April, ...	61272	189407	12254	7118	52319	3085	20115	201150	10207	
	May, ...	77462	235444	154860	8311	50978	3186	10263	102630	5131	
	June, ...	52658	158293	105070	2971	14744	921	6776	67760	3388	
	July, ...	11142	33466	22242	885	5321	332	5	50	1	
	Aug., ...	24383	73280	48717	403	2279	143	...	...	...	
	Septr.,...	49249	117809	98198	1370	8068	501	...	...	...	The value of the trade has been estimated thus: Balumba Salt at 3 Rs. per maund. Sambhar Salt at 4 Rs. per md. The fine Sugar at 8 Rs. per maund, Goor at 3 Rs. per md. Cotton at 10 Rs. per md.
	Oct., ...	85258	255837	170516	4674	33452	2091	196	1960	98	
	Novr., ...	73209	221138	146119	3387	25081	1567	2573	25730	1286	
	Decr., ...	31002	96568	62003	2583	19980	1249	13653	136530	6827	
1845	Jany., ...	40322	134535	80644	2310	16030	1002	17070	170700	8535	
	Feby., ...	34327	103768	68655	2226	13550	847	8962	89620	4481	
	Total,	680977	2084627	1361456	45123	281219	17389	130254	1302540	65125	

7.—The quarries at Roopbass belong to the Rajah of Bhurtpoor. They furnish two kinds of stone, both good; but the grey stone is the best, and the red is somewhat inferior and of a loose grain. The price of the grey stone at the quarries is 13 Rs. per 100 maunds, which I found by actual measurement to represent 68·48 cubic feet. The actual price of this mass is 7 rupees; but in addition the Rajah takes a duty of Rs. 5-8-0, and the Putwaree 8 annas as his fee. This price of 7 rupees, represents the value of the stone quarried into any rectangular form.

8.—The price of the red stone, is, for the same quantity 6 rupees, and the Government duty in addition is Rs. 4-8-0, and the Putwaree's fee 8 annas; and 100 maunds contain by measurement 85 cubic feet. The cost of carriage of 100 maunds weight to Agra, a distance of 33 miles, is on an average Rs. 20; to Muttra, distance 36 miles, Rs. 17; to Bindrabun, distance 41 miles, Rs. 15; but the prices vary with the scarcity or plenty of carriage. There are a greater number of return carts passing to Muttra and Bindrabun than to Agra, and the road is harder and better. This accounts for the cost being less for the longer distances.

9.—A cart laden with 15 maunds and drawn by two bullocks will go five coss or 10 miles in a day. A four-bullock cart will take 30 maunds, the same distance in the same time; and an eight-bullock cart, 60 maunds. This is the greatest load ever taken; 50 maunds is an usual load for an eight-bullock hackery. The above rates are calculated for tolerably hard roads, but if any length of sand intervene a cart will barely make 3 coss in a day.

10.—I applied to the Rajah of Bhurtpoor to inform me what quantity of stone was quarried in the course of the year, and whither it was sent. The last question, he could not answer, but it appears that in 1252 Fuslee there were quarried 1,05,000 maunds of grey stone, and 1,80,000 of red.

11.—The Rajah expressed his readiness to allow the British Government to take as much stone as they chose for the purpose of the road, duty free, but much of the benefit of the road will be lost, as far as the price of the stone is concerned, if the Rajah persist in levying the present extravagant duty.

12.—The other set of quarries are situated at Bhagour, Tautpoor, Kussuktar, Busye and Jugnere, (marked with an asterisk on the map,) and there are altogether 68 quarries open. They furnish both grey and red stone, and the grey stone is very much superior to that of the Roopbass quarries.

13.—The following table shews the result in cubic feet of the measurement of pieces of stone representing the maund weight.

Bhagour quarries :—

	Mds.	
Red stone, -- --	100 = 119·7	cubic feet.
Busye quarries :—		
Red only, -- --	100 = 147·68	„
Grey ditto, -- --	100 = 91·5	„
Tautpoor quarries :—		
Red, -- -- --	100 = 125·8	„
Grey, -- -- --	100 = 71·17	„

14.—The price of the stone at the quarries is per 100 maunds, red Rs. 5; grey Rs. 7; and the cost at Agra is, red Rs. 21 per 100 maunds, grey Rs. 23; the carriage being 16 rupees per 100 maunds. I am informed that the Zemindars have got a monopoly of the carriage of the stone, and that this is the principal source of their gains from the quarries. They allow no one to work the quarries who does not employ their carriage.

15.—The Zemindars levy a cess of 4 annas per adze on the miners, who work the quarries, and the collections made in this fashion, are stated by the Putwaries to be as follows :

1,249 1,250 1,251

44,182 mds. 9 Rs. ; 46,289 mds. 96 Rs. ; 45,269 mds. 201 Rs. ; but this account is evidently as far as the amount of duty goes, unworthy of credit. In some years in lieu of a cess the Zemindars take stone of the amount, of which no account is submitted.

16.—If the Tram Road be made from the quarries of Jugnere to Agra, it will probably run through or near the Customs post of Mulpoorah; I therefore insert an account of the trade of that chowkee.

Memorandum of the trade, that has passed the Mulpoorah Chowkee, from February 1844 to April 1845.

Year.	Month	Salt.			Sugar.			Cotton.		
		Quantity.	Value.	Duty.	Quantity.	Value.	Duty.	Quantity.	Value.	Duty.
		Maunds.	Rs.	Rs.	Maunds.	Rs.	Rs.	Maunds.	Rs.	Rs.
1844.	February, ...	0	0	0	1185	6986	478	7714	77144	3857
	March	14	28	28	1595	5419	505	8403	73270	4200
	April, ...	82	324	168	2402	9893	841	9424	91241	4712
	May, ...	0	0	0	4252	21949	1507	4597	55967	2298
	June, ...	671	768	708	2562	17885	966	2135	17076	1067
	July, ...	178	421	311	816	959	296	61	476	31
	August, ...	122	285	214	482	2304	145	9	64	5
	September, ...	183	419	300	1008	10616	565	7	53	3
	October, ...	326	1170	641	3021	17755	958	84	588	38
	November, ...	128	599	255	3169	15426	868	1030	7945	501
	December, ...	22	64	43	1877	14771	762	6997	55019	3455
	January, ...	439	1748	877	2486	21170	1105	9432	75377	4712
	February, ...	33	132	66	2598	16928	919	12146	97159	6073
	March, ...	92	366	183	3192	18679	1010	10578	84625	5289
	April, ...	736	2795	1479	3912	27713	1450	10311	82283	5147
	Total, ...	3026	9122	5260	35157	208751	12375	82928	711287	41388

M. C. HICKIE,
Deputy Collector.

17.—I am clearly in favor of the road being made from our own quarries of Jugnere. We have a better stone—a cheaper stone. We have no oppressive tax on the commodity as in Bhurtpoor. It is true, that there does not run so great a traffic on the Jugnere and Mulpoorah line, as on the Bhurtpoor and Bichpooree line. But I confess I look more in the first instance to the facility of getting the stone and the lowering its price than to the conveyance of goods. That is to say in the commencement let us get a good supply of cheap stone, and let the practicability of the Tram Road be proved, and we may then run a road from Agra to Dehlie, which will be a real benefit to the commerce of the country. The first point is to get a cheap supply of stone to Agra, and it is clear that for this purpose Jugnere will suit us better than Roopbass.

18.—There is but one thing more that I wish to allude to: that is the necessity of hitting on some contrivance by which the cattle which draw the carts of the country may be made available for the Tram Road, by the native mode the cattle work in the trams, and the smoothness which facilitates the propulsion of the cart interferes with and almost renders nugatory the muscular action of the bullocks.

21.—If successful, besides the advantage of the road for traffic, we shall, as it were, have brought the quarries to the banks of the Jumna; and I have no doubt that the stone will be sold as cheaply at Allahabad as it is now at Agra.

22.—I regret that the information which I have been able to supply has been so scanty, and have the honor to submit all the correspondence that has passed.

ROAD-MAKING IN THE HILLS.

No. I.—*Principles laid down by* MAJOR J. P. KENNEDY, *for the guidance of all persons engaged in constructing the road from Kalka, through Simla, to Kunawur and Thibet.*

Every road should have its line as level, and its surface as hard, smooth and non-elastic, as circumstances under the most scientific management will allow.

The subject of road-making may be divided into two general branches :—

First.—The laying out of the line.

Second.—The construction of the road.

LAYING OUT OF THE LINE.

When the grave charge of initiating the improvement of a district of country, by the construction of roads, is committed to a man of judgment, his first care will be to consider the features of the country, not only within his immediate charge, but far beyond those limits.

He should divide his road projects into three distinct classes. The first and most important containing the lines of general intercourse; the second containing the roads for merely local objects, and communicating with those of the first class; and the third containing the farm roads communicating with those of the second and first. He should not, upon any account, permit the perfection of his roads of the first class to be in the slightest degree injured for the benefit of those of the second or third classes. His great lines of intercourse must be laid out solely with reference to the general levels of the country, and to the permanent markets, to which producers may afterwards have to convey their goods. If he think only of his own little district at this point of his operations, he will materially injure it, as in that case his general lines will probably not be such as to invite general traffic, and the mercantile interests of his district will be proportionally impeded. The co-operation of the circumjacent neighbourhood is essential to the improvement of any given spot of country, and must be earnestly sought for. Keeping these considerations constantly in view, we may now proceed to the rules applicable to all branches of laying out, viz :—

1*st.*—That the line must never rise or fall unnecessarily; it must go round, or cut through impediments.

2*nd.*—That the quantity of ascent or descent, when such is unavoidable, should be divided uniformly over as long a distance of the line as the nature of the ground will permit, and thus the inclination at each particular part will be reduced to the smallest possible rate.

We should recollect that the loads carried along roads must be small in proportion as the inclination of the hills is great; that the steepest hill, in fact, regulates the load.

We must never forget in laying out a line of road, that on an inclined plane or hill, of which the surface is hard and smooth, when any power holds a heavy body in equilibrium, the power exerted will have the same proportion to the weight as the height of the plane or hill bears to its length; and secondly, that whilst the effect of the load increases, the power of the animal employed to draw it diminishes in proportion as the degree of inclination increases. These two facts should never be absent from the road-maker's mind.

When this subject is fully understood, it will be evident that the ignorance of a person who undertakes to lay out a road may, and very often does, make the transport of commodities amount to many times what it should cost. There is little doubt that the greater number of the hills we generally find on roads might have been either wholly avoided, or their inclination very much diminished, by judicious laying out; and the greatest evil is, that the only wise remedy for such blunders is to make a new piece of road where they exist, and if they are numerous, to change the entire line. The common mode of correction is to cut down in some degree the hill, and to fill up a little the hollow; but this method rarely reduces the inclination as low as the natural features of the ground would allow; and it generally costs much more than would be necessary to put the road in its right place by laying it out afresh.

The correction of hills on old roads has been alluded to here, to show the importance of extreme accuracy and sound principles in selecting an original line. Every Superintendent will now understand that if an error be made, it cannot be thoroughly remedied without abandoning that portion of the road where it exists, and taking up a new line, thereby losing the capital already invested, and injuring the speculators whom the road may have brought there; but if there be an error of construction, as for instance, the use of soft materials instead of hard, or the like, all this can be set right without abandoning the old line. The power of getting level roads by cutting through hills and filling up hollows is not disputed; and in laying out a line of railroad this method must be adopted, because the velocity of the steam-carriage will not allow of such rapid curves as a road must take which follows the natural inflexions of our hills; but the expense of such cuttings and embankments is so enormous, that to think of them for the ordinary roads would be quite out of the question. Our necessities frequently require that farm roads should be made, that roads for approaching minor villages, &c. should be made and that extensive districts of almost unexplored countries should be intersected by numerous lines of general communication. If a costly kind of road be attempted in such cases, the necessary results cannot possibly be produced, because the necessary funds could not be provided; still it is essential that as accurate a regard should be paid to their laying out, as if they were to be immediately constructed on the most perfect models, and that the levels be the very best that the nature of the country will admit of. We must provide from the commencement that every successive operation shall tend to bring them ultimately to a state of the very highest perfection, and that nothing shall ever have to be undone.

False ideas of economy and inadvertence frequently lead to the employment of men who do not understand the principles of these essential operations, although they attempt to execute them, and hence the eternal toiling up and down hill to which they, their neighbours, the public, and future generations are condemned. Most amateur artists are time-killers and money-wasters, but of all the amateurs in the world, the road-maker is the most mischievous; there is no method of avoiding his ingenious contrivances to harass the weary traveller and reduce the profits of industry.

The first thing to be done, when it is determined to open a road between any two points, if they be distant, is to get the maps of the adjacent country, and to become thoroughly acquainted with every inch of the intervening ground in all directions, particularly the course of rivers.

If it be a hilly country, the greatest possible attention must be given to choose the most convenient passes of mountains with reference to their height, and the

highest passes of valleys, which in all cases, must be considered as obligatory points of the line. The selection of these, therefore, is to be considered the first and most important point of laying out, and nothing short of *mathematical proof* of their superiority to all other points ought to satisfy the Superintendent that he has selected the right points.

It is much to be regretted that the Survey Department of India has not furnished the public with that most important class of information, a contour delineation of the hills; the want of which must be remedied by increased industry in all those who are engaged examining the country with a view to the selection of the line.

The most disadvantageous circumstances under which it can be required to lay out a line of road is, where the direction runs at right angles across a line of hills, to the passes of which there are no convenient approaches by means of under-features; this obliges us to resort to the expedient of zig-zags. There is no difficulty in laying out such a road to any required degree of inclination; but when done, it is always dangerous, as it is not possible to avoid very acute angles, which, on a declivity, are most objectionable. If an animal run away with a carriage in descending such a road, the first turn he reaches will probably finish the mortal career of the whole party.

The rule in such a case must be, to make as few turns as possible; and in general, there need not be more than one on each side of the mountain.

Having obtained a knowledge of the relative heights, as above described, both from maps, and by taking lines of section with the level, and having thus selected all obligatory points, we may now proceed to the operation of marking out the exact line between all the points thus selected. This is done by fixing up pickets with flags attached, in the required slope, by means of either the plummet-level or a spirit-level, having a graduated vertical limb. These flag-pickets may be placed at intervals of about one hundred yards, more or less, according to the bends in the hills, taking care that one is put at every projecting and every retiring angle of the ground, and that from each picket the one on either side is distinctly visible. We proceed thus until the whole line is picketed off, observing to correct this line if requisite; and it rarely happens that the pickets can be placed precisely in their right permanent position at the first trial.

Having got the long pickets accurately placed, the ground should be distinctly marked at each picket by cutting across, or some other convenient sign; and the second operation must be commenced by placing short pickets with the boning rods at intervals of about eight yards between the long pickets.

Third operation. Having placed the short pickets, long lines are then laid to the foot of the pickets, taking care that the lines run round all obstacles, and not over them. When these lines are fixed, some expert laborers, accustomed to the work, may be placed to cut out the lock-spitting exactly to the level of the line.

This operation should be done with great accuracy, that there may be no necessity for correction afterwards, and handy men, accustomed to the work, should be employed in lifting the lines and laying them again, as the lock-spit cutters proceed. This lock-spitted line being the sole regulator of the levels, must be examined, and re-examined to ascertain that in every part it has been accurately cut. The person charged with such a work must not spare himself at this point upon any account. Let him then bring every one whose opinion is worth having in the neighbourhood, to visit and criticise what he has done; let him reflect that, by any idleness or stupidity on his part, he passes sentence upon countless generations to suffer inconveni-

ence and unnecessary toil for his omissions. The lock-spitted line, when completed, is not to be considered as any thing but a gauge for the general level of the surface of the road. It is not the centre, as some suppose, although, upon a general principle, the nearer the centre line comes to it, the cheaper will be the forming of the road, and the more we diverge from it, the more costly it will be where the features of the country are of a hilly character.

With the completion of the above described lock-spitted mark, neatly cut along the whole length of the projected road, we shall consider the business of laying out the line to have been executed; and in order the more clearly to separate this most important operation from all others, we shall consider the subsequent picketing, ruttings and marking off the details, as appertaining to the subject of construction.

The average cost of cutting this gauge-line or lock-spit, independent of the preparatory surveying and superintendence, ought not to exceed four or five shillings per statute mile,—that is to say, for the actual pay of the laborers employed to execute it; and when completed, it ought to exhibit a perfect level or a perfectly uniform incline, between every two of the obligatory or main points, and following every horizontal inflexion of the ground, it ought to stand the test of any instrument, and be pleasing to the eye. The want of accuracy in the laying out of public undertakings, is the source of that constant doing and undoing, or playing at blind-man's buff with the work, which we so often see; doubling or quadrupling the proper cost, and leaving most discreditable results. The economy and perfection of the work will be in proportion to the judgment and accuracy applied in the laying out and making of this gauge-line, as it gives us the key by which to regulate with the utmost precision, every subsequent effort of every laborer we employ, and to point out where every spadeful of excavation is to be dug, and permanently deposited with the smallest amount of exertion. We shall next proceed to the subject of

CONSTRUCTION.

As soon as the lock-spitted gauge-line shall have been well considered and criticised, and all necessary corrections completed, it may be widened into a 5-feet track. The next operation is to fix the pickets for the centre of the road.

This will regulate first the cost, and second, the appearance of the work when complete. We must avoid objectionably sharp turns; but we must also studiously avoid heavy cuttings and fillings, and we must make our curves regular. These three points can generally be combined; and they must be combined, otherwise, the Superintendent cannot be qualified for his charge. He should never have his eye off the gauge-line, and as each picket is placed, it should be accompanied with a mental calculation as to the quantity of cutting and filling, and consequent cost it will require to bring the road at that point to its proper width, and to the level of the gauge or lock-spit. He will bear in mind that as often as he can place a picket exactly at the lock-spit, without infringing on a principle, he should do so, as then the forming of the road will cost the least possible sum; unless when he has to deal with rock which requires blasting. He must at all times think of his finances, taking care that the amount of money or labor estimated for the work shall be made to complete it, and he will be justly culpable if it fall short, as this consequence is very rarely attributable to any other cause than unfitness in the Superintendent. The wrong placing of a few pickets may cause a piece of work to cost double or tenfold, nay, a hundred times more than it should cost; and it is clear that the man who can perform the most perfect work at the cheapest rate, must at all times earn character in proportion. It

is evident that there may be a very great variety of curves made for rounding off the angle which the lock-spitted gauge-line forms in passing a valley or ravine, and that the more the curve is carried out from the angle, the better will be that particular part of the road, but it must be recollected that the slight improvement thus effected on one spot, is attended with most disproportionate cost; and, if a man deficient in judgment be placed in direction of such works, he may use very fine arguments as to the utility of gradual curves, and the like, but the result will be, that instead of succeeding to fulfil the object of his employer, by opening in its full length a useful line of intercourse, he will find all his money expended on two or three fantastical embankments. He will leave the district as closely sealed up as he found it, and his employer will be justly disgusted with such costly enterprises. If he desire to serve himself, and to be useful to his neighbours, he will follow, as nearly as possible, the natural features of the ground; unless when there is the most indisputable reason against this; and keeping a watchful eye upon the money chest, he will never sacrifice the general result to any chimera whatever. This cutting and banking mania is the grand source of wasteful expenditure in the construction of our roads.

If, instead of going uniformly along the side of a hill, and making our road with the minimum of cutting and filling,—if, instead of this, we seek to torture it into straight lines, still keeping to certain predetermined levels, the line of road must be a succession of deep cuttings and high embankments: costly at first, and costly to the last, from their liability to dilapidation.

As soon as the centre line shall have been cautiously picketed out, all the side lines must be measured from it and distinctly rutted out upon the ground, taking care to lift the several shearsods. These lines will show the verges of the road, the inside and outside of the fences when such are made on the road, and the width of the water-tables, as well as the position of the catch-water drains. Accurate *bonings* must be put in at every picket in the centre line, which will thus be level with the opposite points of the lock-spit gauge, and a correct longitudinal section must be made up between these pickets.

Cross section lines should likewise be made up to the intended level of the road at every 100 yards, showing the precise fall that the road is to have from the centre to each side, when formed. But in making up longitudinal and transverse sections, it is necessary to observe whether the soil be of such a nature as to answer for the soiling, or whether it be of so defective a quality as to require a superstratum to prepare it to receive the broken stones or surface gravel; and a corresponding distinction should be made as to the height to which the section lines should be raised in different places. If the natural soil be of the right quality for soiling a road, it would be an unpardonable waste to require that more of the same description of material should be excavated elsewhere and brought upon it, although we have known such surprising extravagance set forth in specifications. The cross-slope given to a road should vary according to circumstances. If its maintenance and repair be carefully provided for, on level ground a fall of one in twenty-four from the centre of the sides will be sufficient. If there be any doubt as to the future care, the best precaution is, to increase the cross-slope as a security against surface water, and in all cases it is well to make the cross-slope somewhat greater on declivities than on the level ground, in order that the path of all surface waters may be directed in the shortest lines to the water-tables; under these different circumstances, the cross-slopes may be made to vary from one in twenty-four to one in twelve, and they should be accurately proved by the section level.

It is well to know that some authorities on this subject have recommended the cross-slope of roads on declivities to run the whole way from the outside verge to the inside, whilst others advise just the reverse, and not from the centre to each side. The chief object of the first recommendation is, to prevent the corrosion of the outside verge by the surface water, and that of the second to prevent any accumulation of water in the water tables, but they both appear to be most objectionable in practice, as they necessarily throw every carriage off its level, and bring an unequal portion of the load on the wheels of one side. They also give a longer run to the surface waters on the road. No professional man should permit so serious an inconvenience to be inflicted on the public. His ingenuity ought to provide a remedy of a different kind. As soon as the longitudinal and cross sections have been made up to the right level, the work may be considered in a state to employ large forming parties, who after this preparation, can scarcely commit errors, if there be any degree of activity in the overseers.

When the road is constructed upon level ground, it is desirable to make two side fences with water-tables outside of these; when it is on sloping ground, one side fence will suffice, the cut face of the bank forms the other.

It is evident that on sloping ground, the Superintendent, who desires to execute his work with economy, must use every exertion to provide that the quantity of cutting shall, as nearly as possible, agree with the amount required for filling, that he may not be obliged to carry materials either to or from the place where he works.

The materials used for fences, retaining embankments, &c., will depend upon the nature of the soil in a great measure; and the best proof of skill, in this or any other art, is the power of making the most possible out of the circumstances in which we are placed. The man who cannot supply himself from his own vicinity would fail, if he had Guernsey granite and mines of gold at every perch of his progress. When the soil is stony the fences and faces of embankments would naturally be made of this material, and, when built dry, they should have a slope of one-fourth of their height. If sod work be used, the slope should be increased to one-third of the height, and when a bank of earth or other material is faced without being supported, the slope will depend on the quality of the soil, observing to give the greatest slope to the most friable soil, and it is for the Superintendent to observe the natural slope at which each kind of earth will continue. The best soil that we can meet with in constructing roads is gravel; because, in the first place, it has natural drainage; secondly, when the road has been formed in such a soil, it is both soled and metalled unless the traffic be of a very heavy description.

In making a road through any spongy or soft soil, it is well to let the work season after the general drainage and forming have been effected before proceeding further. When embankments are filled up, a considerable allowance must be made for sinking, and after allowing them to season, they should be again levelled up. If these points be not attended to, or if the work be hurried over, it will look well at first, but afterwards it will show many inequalities and defects that might have been avoided.

The liberal use of a heavy roller is an excellent way of consolidating the surface of a new road, preparatory to opening it to the public, and the difference in the quality of both gravel and stones should be well understood by every road superintendent. Some stones can be broken with more profit to the workmen at one anna per ton, than others at six annas, and where heavy carriages are in use, the low priced stone is, in general, the more costly in the end. We must recollect that the

price of breaking the stone forms but a portion of the cost of metalling a road, and the most durable material to be had within any rational limit, as to cost, is at all times the most desirable. Contracts for stoning, therefore, should always specify the precise kind of stones required, and from what quarries they are to be taken; and no one can be considered properly qualified for superintending such works as we are now considering, unless he have acquired a thorough knowledge of the several varieties of rock common in the country, with the different qualities and properties peculiar to each.

When we estimate the cost of a new road, we should divide the whole into three very distinct general heads. The first may include all the expenses of surveying, laying out, forming, draining, fencing, soling, gravelling, and all else preparatory for the stoning. The second head should show the cost of the stoning or metalling, and should detail minutely the quality of the stones required, and the quantity per perch; allowing a larger dimension to the broken stones in the bottom, and a small dimension at the surface. The third, the cost of the masonry, bridges, pipes and tunnels if any.

It is extremely essential to separate thus the great heads of expense, in order to enable *all persons* to understand the way in which the total cost is made up on different descriptions of work, and, as it were, to get rid of that professional mystery which is generally made to envelope every thing relating to the expenditure of money.

The details here included under the first head are such as are required, with but little variety as to their application, in all projects for new roads, and their cost may be made to vary from 100 to 600 rupees a mile, according to the peculiarities of soil in which we are working. The second head, or metalling, may be either wholly omitted in certain cases, or it may be adopted to any degree that the circumstances render necessary. For instance, three tons of tender stone, at one or two annas a ton, may be thought applicable for the exigencies of one case, when in another it might be indispensable to apply twelve tons to the perch of the hardest stone to be had, at a cost of perhaps six or eight annas per ton; thus making the rate for this branch of cost vary, from three or four annas, to 100 annas the perch, according to the means applicable for the construction, and the intensity of the traffic to be expected. The third general head, including pipes and masonry, is also capable of being effected in various degrees of excellence, and at proportional rates of cost, which can only be regulated by comparing the necessity of the work with the funds applicable for its construction.

No. II.—*Hindostan and Thibet Road,—Rules for Superintendents, Overseers, &c. &c.*

Officers employed on the survey of the line are to send in reports of their observations, at least once a week, addressed to Major Kennedy at Simla: these reports to be accompanied by sketch plans and sections. The plans to be on a scale of two inches to one mile. The section horizontal scale to be likewise two inches to one mile, and the vertical Section 200 feet to one inch.

2.—The maximum incline is not to exceed 3 in 100 or 1 in 33⅓; and every exertion must be made to keep the inclines as much as possible *below* this maximum.

3.—The whole line is divided into Superintendent's divisions, and each division to be designated by a letter.

4.—The point from which all measurements are to be taken is marked by a picket sunk opposite Mr. Vivian's house in the Simla bazar.

5.—The 1st division, commencing southward, is denominated the A, or Krole division; the 2nd B, or Simla division; the 3rd C, or Mahassoo division; the 4th D, or Muttiana division; the 5th E, or Kotegurh division; the 6th F, or Teranda division; the 7th G, or Chini division; and so on to the end of the line northward.

6.—All reports to be made on foolscap paper, and marked at the head of the report with the divisional letter, to which the portion of the line it refers belongs, as well as the territory. It will be folded in four, and docketed on the back by the Officer who sends it, with the divisional letter and the substance of the report.

7.—All Officers will be expected to keep copies of their reports, plans and sections, for the convenience of future reference.

8.—All Officers employed in surveying the line, as well as Officers in charge of divisions, and Overseers in charge of sections, and also Assistant Overseers will be required to make themselves thoroughly acquainted with the printed paper containing the "Principles of laying out and constructing the works," that a uniform practice may obtain throughout.

9.—The working parties are to be kept under the superintendence of their respective mates; and each Sapper Overseer is to be appointed to his distinct and separate charge, consisting of one or more mate's parties, according to the strength of the whole party as shewn in the following table:

Composition of an Overseer's party for working a section of 10 miles of the line. { *Two or more Overseers' sections to constitute a Superintending Officer's district.*

Sappers.		Mates and Laborers.														Remarks.
		When Working single force.		*Double force.*		*Triple force.*		*Quadruple force.*		*Quintuple force.*		*Sextuple force.*				
Overseer in charge of Section.	Assistants in charge of Sub-Section.	Mates.	Laborers.	Mates.	Laborers.	Mates.	Laborers.	Mates.	Laborers.	Mates.	Laborers.	Mates.	Laborers.			
1	1	1	50	1 1	50 50	1 1 1	50 50 50	1 1 1 1	50 50 50 50	1 1 1 1 1	50 50 50 50 50	1 1 1 1 1 1	50 50 50 50 50 50			This composition of the working parties will enable one Sapper Company to furnish Overseers for ten Divisions, extending over about 200 miles. It gives us the power to employ efficiently under them from 2,000 to 12,000 men a day.
1	1	1	50	1 1	50 50	1 1 1	50 50 50	1 1 1 1	50 50 50 50	1 1 1 1 1	50 50 50 50 50	1 1 1 1 1 1	50 50 50 50 50 50			Until the line is opened to 6 feet wide, the pickets shewing each man's working ground must be placed when working in clay, or gravel at seven yards apart, and in rock at two yards apart.
1	1	1	50	1 1	50 50	1 1 1	50 50 50	1 1 1 1	50 50 50 50	1 1 1 1 1	50 50 50 50 50	1 1 1 1 1 1	50 50 50 50 50 50			A party working in *double* force would thus cover upwards of ¼ mile in clay, or about ⅓ mile in rock work, and it is probable that the double force would in the first operation be better looked after than a more extensive party. Working our ten Divisions at double force would give us 4,000 laborers. When the widening of the road to its full extent commences, wall building, &c., then the larger forces may be called in with profit.
1	1	1	50	1 1	50 50	1 1 1	50 50 50	1 1 1 1	50 50 50 50	1 1 1 1 1	50 50 50 50 50	1 1 1 1 1 1	50 50 50 50 50 50			One of the Assistant Overseers should always be a miner.
1	4	200		8	400	12	600	16	800	20	1000	24	1200			

10.—During the rainy season the working hours must depend upon the weather, the Overseers using their discretion as to the hours for meals. When the weather however is fine, every party must be at work at 6 o'clock A. M., the dinner hours to be from 11 till 1, and to leave off work at 6 P. M.

11.—As much waste of time occurs in mustering large parties of laborers, when this not done with care, the Overseers are required to put the men at once to work under their respective mates, at the established hour for commencing. The chief Overseer will then immediately go round, and muster each mate's party separately, noticing the absentees. Thus only one mate's party at a time will be diverted from work for this object.

12.—A daily report in the following form will be sent from each party, showing the number of those present, and the quantity of work done during the day, as well as the total number of days' work from the commencement, and the total work done in the section.

Section *Division Road Report,* *day of* 1850.

(Territory of)

	Serjeants.	*Corporals.*	*Native Officers.*	*Native Non-Commissioned Officers.*	*Sepoys.*	*Mates.*	*Coolies.*	*Total.*	Road opened in yards. *Lock-spitted.*	*To 5 feet.*	*Road completed.*	Remarks.
Total brought forward from commencement of work, -- -- -- --												
On day of 1850,												
Total, -- --												

Examined, ————— ————————

In charge of Division. *Overseer in charge of Section.*

These reports will shew the mileage cost in labor at which each Overseer is performing his work, and will afford a good comparative scale of the value of each Overseer, and the names of those whose efforts prove them to be most deserving, will be forwarded for the favorable consideration of Government.

13.—Before the parties are dismissed in the evening, every mate must be informed of the precise point where his squad is to assemble on the following morning.

The distribution of the men, by assigning to each a regular portion of work, marked off by pickets, and sufficient to occupy him for the day, is the most important duty of the Overseer and his Assistants. By this method a fair principle of task work

can be established; and there is no other remedy against idleness, and consequent waste of the public resources. The omission of this practice frequently makes public works cost from 10 to 20 times the proper amount, and every Superintendent and Overseer employed in the present works, will be held strictly responsible for the execution of this essential rule.

14.—The breaking of tools is entirely attributable to the carelessness of the Superintendents and Overseers, by allowing the weaker tools to be applied to the work of stronger ones. The pickaxe and the hoe are frequently destroyed by attempting to remove heavy stones with them; a labor which ought to be reserved for the crowbar, the sledge and wedge.

15.—The present deficiency of crowbars, sledges, mining tools, &c., will gradually be remedied. In the meantime, Overseers must employ the weak tools at the clay and gravelly portions of the work, where, after a 5-feet track has been completed, with convenient passing places 12 feet wide, the width of the road may then be generally increased to 12 feet, with passing places of 18 feet wide at salient, and re-entering angles of the ground, and at other convenient places.

16.—The ultimate width of the road may be considered at 18 feet throughout, with the exception of difficult cliffs, where the width of 12 feet will surface. In every part of the road, a retaining wall, on the side of the precipice, will be requisite to completion, with a parapet raised two feet three inches above the road level. Small weep holes, four inches square, to be constructed under the parapet, for the escape of the surface water, at every 50 feet.

17.—At every re-entering angle of the ground, and at distances not exceeding 100 yards, substantial cross drains must be made under the road, of ample dimensions, to carry off all the water that can be expected in the heaviest rains and in no case, are these drains to be of smaller dimensions than four feet high on the outside, and two feet wide, which is sufficient to admit a man to clean or repair them.

18.—Great care must be taken in preparing sound foundations for all walls which, when built dry, as retaining walls on the outside or precipice, should have a slope of one-fourth of their height, and a thickness, at their foundation not less than one-fourth of the height, plus two feet six inches. These retaining walls it is not desirable to make generally more than four feet high, exclusive of parapets, although many emergencies will render much higher walls occasionally requisite.

19.—In opening the first 5-feet track, where very difficult cliffs occur in the line, temporary tracks may be made either above or below the proper level, as the nature of the case may permit, taking care, after passing the obstacle, immediately to regain the proper level. By this means an immediate passage can be obtained long before the permanent passage could be made in its proper position. And it is desirable that such temporary passages should be above rather than below the proper level, because, in that case, the progress of the permanent track in its proper position along the cliff, will not be impeded by persons passing on the temporary track. These temporary tracks should be suitable for the passage of mules, and they may, in many cases, be made to occupy either the brow of the cliff, which shall ultimately be worked down to the road level, or the foundation of a wall to be subsequently built up to that level.

No. III.—*Labor Works Department.*

Section *Division,* *Hindostan and Thibet Road Return of labor for the month of* 1850.

PAY DEPARTMENT.

Trades.	Names.	Month of 1850.	Total time days.	Daily pay in annas.	Total amount during month. Rupees.	Annas.	Pie.

Trades.	Names.	Month of 1850.	Total time days.	Daily pay in annas.	Total amount during month. Rupees.	Annas.	Pie.

We, the undersigned, hereby certify that the persons above named have been present at work for the time specified opposite their respective names.

Overseer in charge of Section.

Superintendent in charge of Division.

I certify that I have paid to the several individuals above-named the sums opposite their names.

Accountant's Pay Clerk.

We certify that the several individuals in the above list were paid the sums opposite their names in our presence by Mr. ———.

Overseer of Section

Superintendent in charge of Division Work.

FORM OF REQUISITION FOR TOOLS AND MATERIALS.

Required for use at the Tunnel on the Hindostan and Thibet Road :—

5 seers Steel,
4 seers Iron,
1 Dubba Oil.

W. NAPIER.

Simla, 25th September, 1850.

(Approved.)

J. P. KENNEDY.

Received the above articles.

W. NAPIER.

FORM OF BILL FOR TOOLS AND MATERIALS.

DR. -- -- -- -- THE HON'BLE E. I. COMPANY.

For materials on account of the Hindostan and Thibet Road :—

5 seers Steel, @	per seer,	0	0	0
4 seers Iron, @	per seer,	0	0	0
1 Dubba Oil, @	per seer,	0	0	0
Total Rupees, --		0	0	0

(Signed) A. B., *Merchant.*

25th September, 1850.

Certified that the above weights and prices are correct.

(Signed) T. GRAHAM, *Accountant.*

25th September, 1850.

Received the amount of the above Bill in Co.'s Rs. —— Annas —— Pies ——.

(Signed) A. B., *Merchant.*

Certified that the above sum was paid in my presence.

(Signed) C. D.

25th September, 1850.

COWREE-RAM BUND, AND ROADS IN GORUCKPORE.

No. I.—*Letter from* H. C. Tucker, Esq., C. S., *Secretary to the Road Fund Committee of Goruckpore, dated 22nd January 1850, and addressed to* E. A. Reade, Esq., C. S., *Commissioner of the Benares Division.*

Sir,

In obedience to the verbal orders of the Lieutenant-Governor, given on Friday last, in camp at Babutpore, zillah Benares, I have the honor to submit a brief report on the Cowree-Ram Bund. As I leave the district to-morrow, the plans, though correctly done, are not as neat as they might be; and the report, in the bustle of making over-charge of the zillah, is necessarily hurried. In truth, I had hoped to have escaped the necessity of writing a report at all; as I would at any time rather do a thing, than write about it when done.

2.—The city of Goruckpore is cut off from Azimgurh and the districts lying beyond, by the valley of the Amee, which extends about 20 miles from Mr. Robert M. Bird's noble bridge at Chuttace to where the Amee falls into the Raptee below Cowree-Ram. The Amee itself is a deep narrow river, and has two large bridges on the upper part of its course; but during the rains, the whole valley to a breadth of 2½ miles is full of water, and communication with the civilized world almost entirely cut off. It was no uncommon circumstance for a dâk traveller to be detained the best part of a day; and if there was any wind the ferry became dangerous: as for carts or troops, their transit was impracticable.

3.—In this state of affairs, the Goruckpore Committee determined to run a bund across the valley, with some small bridges and a flying bridge, with pucka pier heads at the Amee. The scheme was considered a very wild one, and impossible, by some; but the existing inconvenience was so great, and the advantage of a good Military road in case of war with Nepal, so evident, that it was resolved to make the attempt, and try what could be done; and the sanction of Government was requested, September 17th, 1845. His Honor the Lieutenant-Governor in his reply, dated October 15th, 1845, was pleased to "approve and sanction the scheme," and was glad to observe that so great a spirit of enterprize animated the members of the Goruckpore Committee.

4.—Thus encouraged, the Committee set to work in earnest. The bund might have been carried straight across the valley and jheel; but it was determined in preference to carry it along the water ridge between the Raptee on one side, and the Amee on the other, in the hope that by thus running it along the natural limit between the two rivers, it would be less likely to be carried away. Were it to be done over again, the Committee would carry the bund straight across; as from the deep and extensive excavations for earth, no trace of the original form of the ground is now visible.

5.—It was at first supposed that a height of from 10 to 14 feet would be sufficient; the bund being 40 feet wide at the top, and 60 at bottom, a berm of 30 feet wide being left on each side, between the bottom of the bund and the canals from which the earth was dug.

Season 1845-46.

6.—The work was commenced by 300 prisoners and large gangs of hired laborers on the 16th October 1845; bricks were made and burnt, lime prepared; and the foundations of the Kussiar and Cowree-Ram bridges, of three arches of 18 feet each, laid on 25th December: those of the five arches, Bijra bridge, on the 22nd February 1846.

7.—Quicksands being found under the Kussiar and Cowree-Ram foundations, they were piled. The Birja foundations were 12 feet on a layer of kunkur well rammed down.

8.—The main difficulty was to get tolerable mistrees: Mr. Reade's head-man was dead; and there was no one who had an idea above drain bridges of 12 or 16 feet span. The arches of the Committee's first bridges never therefore exceeded 18 feet. The men, however got bolder in time; and the Committee have just completed an arch of 36 feet span, a very fat ellipse of only 9 feet rise.

9.—To get the bricks in these elliptic arches laid true, was another difficulty. In all bund work, a flat arch is better than a semi-circular one; but the mistrees had not an idea how the bricks should be laid, I had therefore to invent a little machine, of which I enclose a sketch, which easily enabled them to lay every brick true.

10.—During the hot weather of 1846, the Amee was bunded to clear out water from the foundations of a proposed bridge of 8 arches. In this job much trouble was experienced from springs of water. However by the rains, the foundations of the abutments and seven piers were laid, and the walls carried up 6 or 8 feet, to let them settle well before turning the arches.

11.—The other three bridges were completed, but not plastered, before the rains, so that the bund was practicable, with the exception of the gap at the unfinished bridge over the Amee, until the 27th October, when a very heavy flood occurred which topped the bund, and carried away a great deal of earth in spite of all precautions in raising a ledge on the bund, and protecting the more exposed parts by branches of trees. I stood on the bund when the waters were within a few inches of the top, and the waves of the 8 or 9 coss expanse of waters were beating on the range of leafy branches which had been placed to resist them. It was rather a nervous situation for the amateur architect. The great difficulty was to get earth, which could only be got from the high land at either end of the bund, a mile off, and the attempt had soon to be relinquished, and the bund left to its fate.

Season 1846-47.

12.—When the flood cleared away, it was found that two piers and one abutment of the Amee bridge had been completely undermined, the piers thrown flat, and the abutment fairly turned topsy-turvy with the bottom layers of kunkur and brick uppermost in the air. This, though disheartening as shewing the wretched soil we had to deal with, was so far satisfactory as proving the substantial manner in which the bricks had been put together. The whole formed one huge mass, which we had exceeding great difficulty in breaking up, as I had no practical knowledge of blasting, and was afraid of blowing up some of my prisoners.

13.—The prisoners and laborers were again set to work, and the earth-work of the bund was raised from 2 to 5 feet above its former level.

14.—Three new piers were added to the Amee Bridge, and to get out of the way of the insecure foundation of one of the fallen piers, the new one was placed beyond it, so as to make the centre opening 26 feet. These new piers and the new abutment were built on cylinders.

15.—A new bridge of 7 arches of 24 feet span was also commenced near the former Bijra one, and 21 cylinders sunk from 15 to 26 feet, and the abutments and piers carried up to the spring of the arches.

16.—Another bridge of 3 arches of 24 feet span was also built, and arched over before the rains.

17.—It was found that all the Punniar trees, which had been planted at the sides of the bund, although they threw out fresh leaves, and gave every appearance of

flourishing so long as the bund remained soaked with water, withered and died as the bund dried up.

18.—The rains of 1847 were even heavier than those of 1846, and the floods higher than had ever been known by the oldest inhabitant. On the 7th October, the bund was completely over-topped, the water reaching to the cornices of the bridges, 3 or 4 feet above the crowns of the arches, and carrying away a great deal of earth. However the four completed bridges stood the strain bravely, as also the tall pier walls of the 11 arched Amee bridge, not one of which gave in the least. This was creditable to the masonry; as with such a rush of water and without the supporting thrust of arches, it would not have been wonderful had some of these high pier walls given a little.

Season 1847-48.

19.—Guided by this extreme flood, all these piers were raised three feet higher before turning the arches so as to allow full waterway; whilst the central elliptical arch of 26 feet allows of the navigation continuing unimpeded.

20.—Of the unfortunate new Bijra bridge, one abutment and two piers, although built on cylinders, were completely rooted up and upset, the cylinders and piers lying unbroken flat on their sides, and the abutment flung aside in two huge masses; whilst, were part of the bund had stood, there was a deep koond for 250 feet.

Season 1848-49.

21.—This was trying. It seemed as if the more pains were taken to lay deep and good foundations, the worse the work was, and of course the feeling spread that the scheme really was impossible, and that the bund could not be finished.

22.—The Goruckpore Committee, however, were not disheartened, but determined to bridge the whole koond, which might be supposed to be the extreme waterway required in the severest flood, by a new bridge of 15 arches of 24 feet span each. Syud Ilahee Buksh, an old distinguished thannahdar, who had built several bridges in Azimgurh, was called to the work; and by dint of hard work the whole 15 arches were completed, and the bridge and bund made passable from end to end before the rains.

23.—The rains of 1849 were happily slight, and all the bridges and bund remained uninjured.

Season 1849-50.

24.—The laborers have nearly all been dismissed, and the 300 prisoners are busy in plastering the bridges and in building a connecting wall between the two Bijra bridges. The soil there is so very bad, that the earth will not stand at all, even though the Committee took merely the upper layer of the neighbouring jheel; and they have been therefore obliged to build a supporting wall to prevent the earth slipping away.

25.—The whole of the sides of the bund have been thickly planted with coarse grasses and reeds, and the upper edge with different forest trees which are now getting on nicely.

26.—The Committee believe the bund to be now quite safe and sound; but if kunkured, so much the better.

The waterway is as follows:—

1	bridge of	15	arches, each	24 feet span,	360 waterway.
1	ditto	11	ditto,	26 & 18 feet	206
1	ditto	5	ditto,	18 feet	90
1	ditto	3	ditto,	24 feet	72
2	ditto	3	ditto,	18 feet	108
6	ditto	37	ditto,		836 feet waterway.

27.—The earth-work at present is 13,144 feet, or about 2½ miles long; 20 feet roadway and 80 feet at the bottom with berms of about 20 feet, and the average height is now about 18 feet.

28.—About 300 prisoners and 262 hired laborers on an average, have been employed on the work under the superintendence of Moulvee Reza Allee, tuhseeldar, Moozuffer Hoosein, jail darogah, Syud Ilahee Buksh, thannahdar of Amorha, and Ubdool Nubbee, thannahdar of Bunsgaon, to all of whom the Committee feel much indebted for their zealous and gratuitous labors. They deserve to receive the thanks of Government. Soobrattee mistree has also done good service.

29.—The expenditure has been as follows:—

Season of 1845-46,	-- -- -- -- --	Rs.	17,738	14 7
Ditto 1846-47,	-- -- -- -- --	„	18,140	1 5
Ditto 1847-48,	-- -- -- -- --	„	8,913	4 11
Ditto 1848-49,	-- -- -- -- --	„	17,037	12 3
			61,860	1 2
Ditto 1849-50, to this time,	-- -- --	„	6,704	15 8
	Total,		68,595	0 10

30.—One main result of the Committee's experience is this, that in Goruckpore, it is best to build bridges on the upper crust, without any foundation. Wherever particular pains have been taken to sink good and deep foundations, there the misfortunes have always been greatest, whilst adjoining bridges without any foundations have stood firm.

31.—The most gratifying result, however, has been the unusual mark of the approbation and confidence of Government in the spontaneous grant of Rs. 30,000, to assist the Committee in carrying on their public works.

32.—In closing their report on the Cowree-Ram bund, the Committee cannot but again call the attention of Government to the impolicy of tying the legs of the Executive Engineers to their desks, instead of having accountants to examine and keep the accounts, and leaving the Engineers free to run about their divisions and give their most valuable aid to the Local Committees. This Committee, with the exception of a slight sketch of a bridge, has received no assistance whatever from the trained Engineers of Government, and has consequently had to feel its way as it best could. It is absurd that large and important works should be left to mere amateurs, whilst the Engineers, who could direct them skilfully, are confined to mere desk-work, and allowed to remain almost useless. The present Barrack Master system is utterly bad; and the sooner it is mended the better. Till then even with the very best intentions, Magistrates and Committees must waste much money in experimenting. They do not pretend to Engineering skill, and all they can do is to do their best.

P. S.—I have been examining the bund and jheel to-day, and it appears very clear that the jheel to the westward is rapidly silting up. In a few years the canal on that side will be filled up and the lands raised several feet. This will be a new protection to the bund, and may prevent the Raptee coming this way.

It may be useful, perhaps to remark, that none of the Committee's bridges cut their bunds, as is so frequently the case elsewhere. The reason is, that two spouts are allowed to each arch, so that all the rain water which falls on the bridge flows off by

the spouts, instead of draining off to where the bridge is attached to its embankment, and cutting the embankment off: thus leading to the common sight of a fine bridge standing detached by itself, its embankment cut, and no means of getting to the bridge, travellers quietly wading through the water below it. Mr. Bird's Chitaee bridge requires these spouts; half the embankment being regularly washed away every year by the rain water from the bridge.

No. V.—*Minute by* E. A. READE, Esq., C. S., *Commissioner of the Benares Division, on the subject of the roads in the Goruckpore district, dated 23rd February 1850.*

Review of the subject *ab initio.*

1.—The subject of the roads in this district having recently elicited comments, it will be useful to take a review of past operations, and the principles which guided them from the first establishment of the fund to the present time.

State of the district communications prior to the settlement.

2.—The communications of the country prior to the settlement, and I speak from experience extending back upwards of 20 years, were little better than cart tracks. The Muhajun's bridge over the Teraina between Cowree-Ram and Gola Gopalpoor was the only bridge, except the small Towee-ka-pool, over a nullah between the north and south parts of the town of Goruckpore, which existed, before the cession of the district, as the indications of former enterprize. No bridge has ever yet been built by the Executive Engineer in this district, though our tenure of it has approached to half a century, and it was not till 1821 that Mr. R. M. Bird first set the example of constructing bridges over running streams. The bridges over the Sowabowee, the Amee and the Teraina, besides those in the south of Goruckpore, remain lasting memorials of his energy and abilities. He restricted his attention to the valley of the Raptee and the Gogra, evidently because the principal commerce of the country passed to it to and fro of the productive portions of this district, and those south of the Gogra.

First measures since the establishment of the Fund. The Hurveylee Forest.

3.—As the survey of the district proceeded, and the assessment increased also, it became manifest that the future capability of the former to meet the pressure of the latter depended on the extension of commercial intercourse, and the use of roads and rivers. It was of the first importance that cart tracks should be made thoroughfares to the main river of the district, the Gogra, or elsewhere recognized as roads, to prevent appropriation of the land; and this was easily accomplished.* But the barrier between the fertile parts of the district east and west, the Hurveylee forest running up diagonally to the Terai was the difficulty to be overcome. The first exertions made were to pierce this obstacle at several points in longitude as well as latitude. Roads Nos. III., V., VI., VII., XVIII., XXXII. and XXXVII. were thus opened through heavy jungle.

Next classification of roads.

4.—The next step was to classify the communications of the district. The settlement was completed, and thus enabled them to be classed pretty accurately according to their relative importance. Three classes were established,—1st, of main Military and Post roads,—2nd, of Commercial roads,—3rd, of Bye roads.† Experience has shown that the estimate thus

* It was reasonably supposed, that by making cart tracks to any river good roads, bazars would spring up at the terminus. In most cases, experience has shewn the correctness of the anticipation.

† 1st class roads, 50 to 40 feet wide,—2nd class, 30 to 40,—3rd class, 20 the minimum.

formed of each road has not, during the course of events in the last ten years, been affected so as to render a re-classification necessary.

Original design for improvement of roads how frustrated.

5.—My original design was that the surveyor should lay down new lines of road through the pergunnah allotted him for survey, preparatory to correction of the sinuosities in almost every road, which had been made simply by conversion of a cart track into a thoroughfare; but the surveyors were required elsewhere and were hurried off. With the exception of Lieutenant Lawrence little aid was rendered by any, and frequent applications to the Sudder Board for the services of an Assistant Surveyor and the necessary instruments, only received the reply that neither could be spared. Mr. DeSilva was at length deputed to the district, and some partial reforms were effected with his aid. It may be remarked as a general observation that though the lines of communication have been fixed, the process of abbreviation by correction of sinuosities is still a desideratum. This remark does not apply to the new lines cut through the forest.

Latitudinal parallels.

6.—Before systematically undertaking this improvement, it appeared to be more a matter of necessity to complete a series of latitudinal parallels east and west of the district. Southward there existed first, the road from the little Gunduck on the left bank of the Gogra to Fyzabad; second, from Samere Bhagahuttee through Goruckpore to the same point. Northward, in adherence to this principle, the junction between the Gunduck and Raptee, or Perrowna and Mhendawul was first effected; and subsequently a line was opened from Boggah through Goortee ghât on the little Gunduck, and Subeya, to the Dhumaila: but the line between that point and Bansee is still incomplete. A design to extend the line of road, along the Nepaul pillars on the north face of pergunnah Bansee through the intruding portion of the Nepaul territory and along the line of the frontier to the great Gunduck, was abandoned, the nature of the country and the impracticability of boats navigating so far up that river, owing to the force of the stream and the quantity of trees imbedded in the channel, being conclusive arguments against the success of the project.

Principles adhered to by Committee.

7.—The principles which regulated proceedings while these measures were in contemplation and progressing may be briefly stated: 1st, the future operations of the season were determined at an annual meeting of the Committee. 2nd, main roads were annually put in good repair; commercial roads received ordinary mending annually, and were repaired effectually once in three years: bye-roads were kept passable annually, and a discretion was left with the Superintendent to repair them effectually as he deemed necessary. 3rd, savings were annually accumulated for the purpose of building bridges on a scale which required the aid of professional experience. 4th, members of Committee were elected from residents in the interior of the district, whose advice, suggessions and reports were made the subject of resolutions of the Committee at their annual meeting, or at special meetings when such was deemed necessary. 5th, the tehseeldars were directed to report to the Collector on the state of each road in his jurisdiction, and in some cases were necessarily charged with the duty of superintending the necessary repairs; but the system of contracts was preferred.

Savings made annually for the purpose of bridges.

8.—In several places, embankments as approaches to bridges were raised, and bricks made and burnt for the latter elsewhere. In some instances bridges also were completed, but as I do not pretend to be an Engineer, I deemed it right to abstain from entering upon any very

extensive work, and better policy to incur a small annual charge for temporary bridges, and steadily to accumulate the funds necessary for the erection of suitable permanent structures of this description. I was thus enabled to place a sum of Rs. 50,000 at the disposal of my successor in office.

Several good bridges built.

9.—During the last five years the contributions to the register of bridges, which it is one of the laws of the Committee to keep up and revise annually, have been numerous and important. Whatever may be the difference of opinion regarding the chief work to which Mr. Tucker has applied his mind and energies, its comparative utility or prospective durability, the number of excellent bridges erected by him in other parts of the district, are more than sufficient memorabilia of his usefulness. The district roads doubtless are not in such order as could be desired, but at least they are practicable, the commerce of the country is not impeded, the thoroughfares have not been absorbed. The restoration of a road, at least in this district, is a simple matter, but the construction of a large bridge requires experience and talent of a particular order. Mr. Tucker will have made a good use of time and money, even if his greatest undertaking proves a failure, and I do not think this district can be better cared for in after years than by alternate changes in the executive, of officers content to make good roads, and capable and willing to build good bridges.

Suggestions in the matter of roads.

10.—It will probably be deemed advisable to give the benefit of the annual income, now in course of realization, to the effectual repair of the roads, and a few suggestions, the result of experience and observation, may be useful. In several parts of the road, where the soil is light, the road is now below the level of the country. Besides the scrapings from the kennel, earth must be added, and this should not be taken from the fields as is too often the case, but from a trench three or four feet wide on one side of the road. The depth of the trench will be in proportion to the quantity of earth required. There should be a small margin between the trench and the kennel of the road. If the excavation of this trench be even, it will be useful to the owner of the field for future irrigation. This *modus operandi* was tried on the Pipratch road between Puttrah and the forest, and answered well. In dhoos or pure arenaceous soils, accumulation of it on the road is only an aggravation of evil. These tracts are usually not extensive, and in such places the road should have a superstratum of firmer soil, or be metalled, if kunkur can be obtained. Generally in this district grass should not be separated from the top dressing, as it binds the soil, and enables it to resist the action of high winds. In the terai portions of the district, it is a most grievous mistake to remove the sod. The only repair these roads ordinarily require is to fill in the indentation of the hackery wheel with turf; in renewing approaches to bridges it is a prudent precaution to maintain a slope from the bridge downwards to the commencement of the approach. In cases of excessive inundation, the surplus waters thus find away of escape, and the safety of the bridge is ensured.

Correction of sinuosities. Procedure recommended.

11.—The desideratum, as I have above stated, is the correction of sinuosities in the principal thoroughfares. The people have long been prepared for this improvement, and will generally be found very reasonable. In correcting a circuit as the roads are universally wide, one thing is certain that the area of the old will always exceed that of the new cut; years ago when this subject was discussed with a native Committee of land owners, their remark was, that the tenure of land hard by a crooked road was never safe, the road would sooner or later be straightened, and therefore the sooner

done the better. If these precautions were taken there would not only be no grievance, but the owner of fields on the new line would often be a gainer: 1st, the line to be laid down in the dry months when the crops were off the ground; 2ndly, the line taken to be made the next year or rent paid for it if deferred; 3rdly, the old road to be measured, and divided amongst those whose fields were taken up all or in part by the new line; lastly, that the line be marked off either by the Collector or by a Surveyor with a theodolite. In this way the most circuitous road in the district from Barhul to Bhowapar was made straight without a single complaint, and it was admitted in many instances that the old road was more productive to the cultivator than his former land. If a standing crop must be cut down, there is one and but one way of settling the question of compensation, viz. by a summary punchayet on the spot and cash paid down.

Main road No. V.

12.—I think the road No. V. might be first subjected to this improvement with advantage, being I think about the most crooked of the main roads, and where the alteration is likely to be hailed with satisfaction, and would serve as a precedent for others, that of No. VIII. being now of long date and forgotten. On the same road, if practicable, I suggest the construction of a bridge over the Môn Nuddee, the bricks for which were burnt six years ago.

Commercial road No. XVI.

13.—Of commercial roads one only appears to require a suggestion from me. No. XVI. is the great commercial road of the district; and for the safety of Mr. Bird's bridges upon it, inspection and effectual repair appear to be necessary.

Northern parallel what is required.

14.—Of other roads too I need only also note one. It would be as well to complete the northern most parallel from the Dhumaila to Banse, and to construct a bridge of masonry pier, and saul timber platform over the Powye Nuddee, at the point where the parallel and the main road No. III. cross each other.

Suggestions in the matter of bridges.

15.—To the above suggestions I would add others connected with bridges in this district. Mr. Tucker recently pointed out the advantage of furnishing bridges built by his predecessors with spouts through the parapet walls to carry off rain falling on the bridge, which, as he observes, otherwise makes rifts in the earthen approaches. In the jungle and terai it will be safer to lay platforms of saul beams, cross-pieces, chylas, earth and kunkur over all, on masonry piers, built up on jainowots or curbs of jamun wood (which does not rot in moisture) than to build arched bridges. The small brick called the Lakhowree is better suited for bridge piers than the large brick used in other buildings. Every notable bridge in the district should be inspected and reported upon by some competent person at least once a year.

MEMORANDUM—BRIDGES IN THE GORUCKPORE DISTRICT.

			Arches.	*Value.*	
No. 1	Sohun Loll, a Muhajun of Benares, ...	Teraina, ...	9	10000	10000
2	W. M. Bird, ...	Amee Nuddee, ...	7	6000	
3		Sowa Bhowa, ...	3	4000	
4		Teraina, ...	3	3000	
5		Great Mukuneya, ...	3	3500	
6		Toorkmanpore, ...	3	1600	
7		Burial Ground, ...	1	1600	19700
8	J. Armstrong, ...	East of Cantonments, ...	3	2800	2800
9	E. Currie, ...	Towee's Pool, ...	1	650	
10	Ditto, ...	Captaingunge, ...	3	2500	1350
11	E. A. Reade, ...	Little Mukuneya and Busseadeeh,	4	3700	
12		Goreya Bagh, ...	3	1600	
13		Koorna Nuddee, ...	3	1550	
14		Silhenee ditto, ...	3	1300	
15		Teraina, ...	3	2191	10341
16	H. C. Tucker, ...	Jhurrye Nuddee, ...	3	3000	
17		Toora ditto, ...	3	1435	
18		Fureed ditto, ...	3	1865	
19		Saeginwah, ...	2	1803	
20		Amee, ...	9	11826	
21		Khuleelabad, ...	1	606	
22		Khood Nallah, ...	1	1113	
23		Kutnya, ...	3	2363	
24		Oorwara, ...	2	936	
25		Khajera, ...	1	695	
26		Muchooe Nallah, ...	3	1220	
27		Munwarama, ...	5	6809	
28		Goorgahwa, ...	1	772	
29		Ramrekha, ...	3	3493	
30		Boornya, ...	3	1350	
31		Kwana, ...	5	21000	
		Cowree-Ram.			
32 to 39		One Bridge, ...	15		
		One ditto, ...	11		
		One ditto, ...	5	81547	
		Four ditto, ...	3		
40		Duldulha, ...	3	6000	
41		Toora Nuddee, ...	5	4000	
42		Furhein, ...	6	6000	157833
		Grand Total, ..			203824

PART IV.

MEMORANDA ON THE MODE OF SURVEYING ADOPTED IN THE REVENUE SURVEYS, FURNISHED TO LIEUTENANT OCHTERLONY, MADRAS ENGINEERS.

By MAJOR WROUGHTON, *Deputy Surveyor General.*

The Maps forwarded* have been compiled with due care to accuracy, and if it should so happen that you are conversant with the theory of the matter, I doubt not that you will have readily comprehended our mode of proceeding on the Bengal Revenue Surveys; but as the nature of the operations is different, according to the features of the country in which they may be carried on, it seems advisable that I should offer some advice upon the mode of proceeding, adapted to the peculiar circumstances of the case.

As regards the instruments used, a very brief description will suffice · the variety of them being extremely limited.

First.—Theodolites, chiefly manufactured by Troughton and Simms, are those commonly in use, and as they are graduated on the horizontal and vertical limb to single minutes, our calculations do not proceed beyond that limb.

Second.—A brass staff which is applied to the head of a Theodolite stand, and is so arranged that it can be adjusted to the true level, and having a revolving motion, admits of either perpendicular line being directed to an object; probably, when I describe the cross staff in common use, which is a square of wood, ten inches the side, and one inch thick, and sawed half through the diagonals, the design will be at once explained. This instrument is sufficient for all angular work likely to be required on limited topographical surveys, but where it is not so, I use two small Achromatic Telescopes fixed to each other, so as to admit of the vertical lines of collimation being centrically brought to a right angle. These Telescopes are fixed on a circular plate attached to a tripod head, and admit of being levelled in a similar manner to the common cross satff. These Telescopes can direct on long distances, and I have found by experience, are more easily managed than any description of Theodolite. Nor is this the only advantage secured: the fluctuating indications of the magnetic needle are obviated, and a means of circumventing upon precise data, the cultivation, and waste details of villages, is afforded, superior in point of expedition, and simplicity to any mode I have ever seen adopted; while it ensures every requisite fidelity in the operation and results.

The application of this method can be undertaken by any one who can read and write, and the notation being confined to a record of the course, either right or left, every chance of confusion or error is avoided by the simple note R. or L. at the commencement of a new station.

* Specimens from volume of Sohagpore.

Third.—Iron Gunter's chains.

Fourth.—Bamboo flags surmounted with white and blue cloth. The bamboos being straightened by fire, and a plummet attached to the pole, at about 5 feet from the ground, are the most conveniently portable objects that can be used; and if kept on the perpendicular by the direction of the plummet, admit of excellent angular measurement being carried on upon them.

Fifth.—Ten feet rods for measuring offsets.

These comprehend all the implements used in conducting the survey.

In advancing the field work, it is necessary that the angles be read upon the whole limb, for thus the error of graduation is obviated. The outward, as well as the inward, angle is observed at each station, the addition of the two amounting to 360, establishes the correctness of the angular measurement. This mode of proceeding takes place at every station of a given circuit, and the total amount of the actual angular measurement of the polygon, being equal to twice as many right angles as the figure has sides, *minus* the angles at the centre, is a proof of this much of the work being accurate. The survey is invariably conducted upon the system of co-ordinates, the azimuth of the first station line being the element on which the survey is based: thus the measurement of one village azimuth forms the ground work of the calculation of another contiguous to it, and a fourth to the third, and so on to the completion of the entire survey; the value of the azimuth last calculated corresponding closely with the same line determined from a new meridian, verifies this important process of the operation.

The chain measurements are conducted with every possible care, and an iron arrow being driven into the ground with a wooden mallet, leaves a durable mark, and precludes a chance of a miscalculation should the arrow even (which is not likely) be disturbed by the chain.

Error would be sure to arise from the elongation of the chain, which must occur after a little use; but this evil can be easily obviated by applying at intervals the chain to a standard measure, and cutting off from one extremity, the quantity that may appear in excess.

The calculation of the meridian and perpendicular distances rests upon the sine and cosine of the angle and distance measured, and is similar in the process to that which is explained in every work upon traverse surveying.

Hutton, in his volume of Mathematical Tables, in speaking of the Traverse Table, page 174, 5th edition, observes—"that this mode of surveying large tracts of lands as a country, &c., was made use of by Mr. Norwood, so far back as 1635, and he adds, that in plotting the survey of a country thus taken, the circuit station lines, though consisting of many hundreds, may be reduced to a few for the first closing, and the like for the intermediate of each line first plotted, by which every station may perhaps be more truly placed than by any other method." The above remark is extremely accurate, and there is no mode so efficacious as the one advised. By it can be carried on a survey methodically and accurately, and the operation is wonderfully simplified, which by any other process would be involved in difficulty, error, and confusion; and since the meridian and perpendicular columns of the Traverse admit of the station lines being plotted by mere plane scale and compass, it would be difficult by any other method to effect this part of the work so easily, and by no means could a circuit measurement and its area be made and determined with the precision the universal theorem admits of.

It is necessary that the distances on the meridian and perpendicular should be balanced by fixed rule, and one that will secure the distribution of differences in a manner calculated to neutralize the discrepancy.

On the Bengal surveys, it is usual to reduce the calculations by either Boileau's, or Egerton's Traverse Tables. From these the latitude, and departure for every course, and distance will be easily derived, and if the survey of a given circuit be truly made, the sums of the northings and southings will be equal, and also those of the eastings and westings. In the next place, with the view of determining the meridian distances, such places must be selected from the columns of eastings and westings, as will admit of a continued addition of the one and subtraction of the other. By this means the inconvenience of changing the denomination of either of the departures will be avoided.

I may observe, however, that in actual practice, the columns of latitude and departure will not balance exactly; for little inaccuracies must arise from the observations and chaining in the field, which no care could obviate. To adjust these differences previous to defining the meridian distances, the rule is, that on limited surveys, should the discrepancy amount to 1-5th of a pole for every station, it will be clear that an error has been made in the field measurements, which must be discovered by a re-survey. When differences however are not within those limits, the columns of northing, southing, easting and westing, may be corrected thus:—Add all the distances into one sum, and say, "as that sum is to each particular distance, so is the difference between the sums of the columns of northing and southing belonging to that distance." The corrections thus found are respectively *plus* when they belong to the less of the two columns of northing and southing, and *minus* when they belong to the greater. If the course be due east or west, the correction is always additive to the less of the two columns of northing and southing. The correction of eastings and westings, is found exactly in the same way.

In the following example, the sum of the distances is 79', and the difference between the columns of northing and southing is 4, also the first distance is 70; say then

791 : 70 : : 4 : ·01:—which fourth proportional ·04, is the first correction belonging to the southing 53·06, from which the correction ·04 should be substracted.

In this manner the several corrections of the southings

$$\left.\begin{matrix}53{\cdot}6\\29{\cdot}1\\135{\cdot}7\end{matrix}\right\} \text{ are found to be } \left\{\begin{matrix}{\cdot}04\\{\cdot}09\\{\cdot}07\end{matrix}\right\} \text{ respectively.}$$

But as only two of these corrections amount to half a tenth, we must use ·18 for each of the corrections ·09 and ·07; and neglect the correction ·04 : thus the correct southings become 53·6, 29·0, 135·6.

In like manner from the remaining distances we obtain to

$$\text{the Northings} \left\{\begin{matrix}62{\cdot}9\\101{\cdot}1\\54{\cdot}0\\00{\cdot}00\end{matrix}\right\} \text{ the additive corrections } \left\{\begin{matrix}{\cdot}04\\{\cdot}06\\{\cdot}03\\{\cdot}07\end{matrix}\right.$$

And consequently by neglecting ·04 and ·03, and using 1 for each of the two ·06 and ·07, the northings when corrected are 62·9, 101·2, 54·0, 00·1.

In obtaining these corrections, it is commonly unnecessary to use all the significant figures of the distances; thus for the ratio of 791 to 70, we may say as 80 to 7.

The latitudes and departures being thus balanced, proceed to insert the meridian distances of the above method, where we still make use of the same field notes, only changing clains and links into perches and tenths of a perch. Then, by looking along the column of departure, it is easy to observe, that in the columns of eastings opposite station 9, all the eastings may be added, and the westings substracted, without altering the denomination of either., Therefore by placing 46·0 the east departure belonging to this station, in the column of meridian distances, and proceeding to add the eastings, and subtract the westings, according to the rule already mentioned, we shall find that at station 8 these distances will end in 00, or a cipher, if the additions and subtractions be rightly made; then multiplying the upper meridian distance of each station by its respective northing, or southing, the product will give the north, or south area, as in the examples already insisted on, and which is fully exemplified in the annexed specimen. When these products are all made out, and placed in their respective columns, their differences will give double the area of the plot, or twice the number of acres contained in the survey. Divide this remainder by 2, and the quotient thence arising by 160 (the number of perches in an acre), then will this last quotient exhibit the number of acres and perches contained in the whole survey; which in this example may be called 110 acres, 103 perches, or 110 acres, 2 roods, 23 perches.

14.— The information for area, &c. is obtained in any work that treats upon traverse sailing, or close topographical mensuration. It is fully explained in Adam's Geometrical Essays, but more particularly in an American work called "Theory and Practice of Surveying, by Robert Gibson," in which also you will find a full explanation upon all the points.

18.—The above explanation shews the style of a Revenue Survey which embraces all villages situated in a campaign, or well cultivated district. The mode pursued in a less favored, and hilly country, is as follows:—

Secondary triangles, based if possible on primary triangles of the great Trigonometrical Survey, are first established, and a Circuit Survey by traverse is effected of every sub-division, or pergunnah of the district under Survey. It not unfrequently happens that these districts are densely wooded, so much so as to render it impracticable to connect a measurement of one village with that of another with any reasonable degree of expedition. In this difficulty a very easy means presents itself, and it is that explained to you in document G. The true position of the village is determined by ascertaining the value of angles subtended from it to three points of the surrounding secondary triangles; the azimuth of the lines connecting the latter give the azimuth of any of the lines of the subtended angles from the points in question, on which the cross staff is applied, and thus a series of perpendicular lines are made to traverse the cultivation, and waste details. This rule is, as already explained the "theorem of the three points," and is explained in Adam's Geometrical Essays under the head of "Curious and useful Trigonometrical Problems," at page 169, 4th edition, London, and the rules for obtaining the Geometrical construction are as follows,* and which to a Field Surveyor who is able to protract his memoranda on the ground are of much utility in application.

* See Appendix.

APPENDIX.

General Rule for finding the Meridian distances.

The meridian distance and departure being both east, or both west, their sum is the meridian distance of the same name.

The meridian distance and departure being of different names, that is, one east and the other west, their difference is the meridian distance of the same name with the greater.

Thus on the first method of finding the area, as in the following field book:—

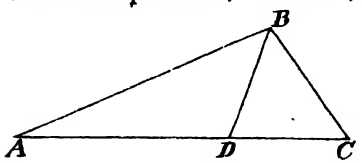
The first departure is put opposite the northing, or southing of the first station, and is the first meridian distance of the same name. Thus, if the first departure be east, the first meridian distance will be the same as the departure, and east also; and if west, it will be the same way.

The first meridian distance,	6·61	E
The next departure,	6·61	E
The second meridian distance,	13·22	E
The next departure,	1·80	E
The third meridian distance,	15·02	E
At station 5, the meridian distance,	5·78	E
The next departure,	7·76	W
The next meridian distance,	1·98	W
At station 11, the meridian distance,	0·12	W
The next departure,	5·84	E
The next meridian distance,	5·72	E

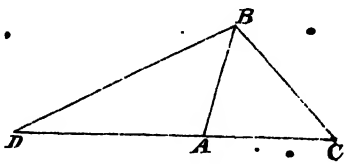
DOCUMENT G.

Townley's Theorem, or the Theorem of three points, in all its varieties. The mutual distance of three remote objects being given, with the angles which they subtend at a station in the same plane, to find the relative place of that station.

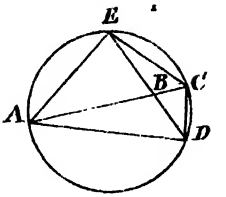
Let three points A, B and C, and the angles ADB and BDC, formed at a fourth point D, be given; to determine the position of D.—First, suppose the station D to be situated in the direction of two of the objects, A and C.



All the sides AB, AC, and BC of the triangle ABC, being given, the angle BAC is found; and in the triangle ABD the side AB, with the angle at A and D, being given, the side AD is found, and consequently the position of the point D is determined.



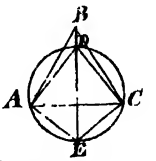
Secondly, suppose the three objects ABC to be in the same direction.



Describe a circle about the extreme objects AC and the station D, join DA, DB and DC, produce DB to meet the circumference in E, and join AE and CE.

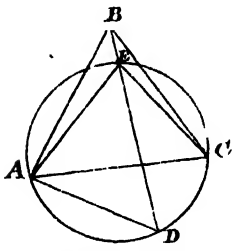
In the triangle AEC the side AC is given, and the angles EAC and ECA being [Euclid III. 21] equal to CDB and ADB are consequently given, wherefore the side AE is found. The triangle AEB having thus the sides AE and AB and their contained angle EAB or BDC given, the angle ABE and its supplement ABD are found. Lastly, in the triangle ABD, the angles ABD and ADB with the side AB are given; whence BD is found. But since the angle ABD and the distance BD are assigned, the position of the station D is evidently determined.

Thirdly, let the three objects form a triangle, and the station D be either within or without it.



Through D and the points A and C describe a circle, draw BD, cutting the circumference in E, and join EA and CE.

I.—In the triangle AEC the side AC and the angles ACE and CAE which are [Euclid III. 21] equal to ADB or its supplement and to BDC or its supplement, being given, the side AE is found.



II.—All the sides of the triangle ABC being given, the angle CAB is found.

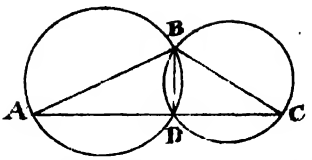
III.—In the triangle BAE, the sides AB and AE are given, and the contained angle EAB (being either the difference or the sum of CAE and CAB) is also given, whence the angle ABE or ABD is found.

IV.—In the triangle DAB the side AB and the angles ABD and ADB being given, the side AD or BD is found, and consequently the position of the point D with respect to A and B is determined. By a like process the relative position of D and C is deduced; or CD may be calculated from the sides AC, AD and the angle ADC, which are given in the triangle CAD.

It is obvious that the calculation will fail, if the points B and E should happen to coincide. In fact, the circle then passing through B, any point D whatever in the opposite Arc ADC will answer the conditions required, since the angles ADB and DBC being now in the same segment, must remain unaltered.

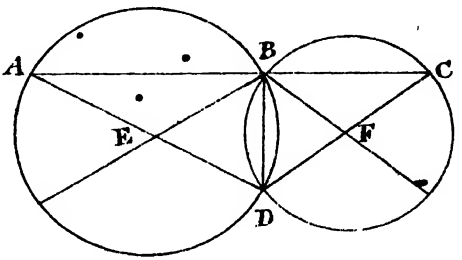
This third case, in which the three objects form a triangle, involves the conditions under which the problem has in general to be solved; the first case in which two of the objects, and the second in which the three objects are in a line, occurring but rarely. The reader will, however, doubtless have been impressed with the extremely laborious nature of the solution which this case involves, demanding no less than four separate trigonometrical calculations before the required answer is obtained. It would evidently therefore be a most tedious process, and one but little suited to practical purposes; other means have therefore been devised of solving the problem, which are better suited to practice.

The first of these consists in a geometrical construction. Let A, B and C be the three Stations, and D the position of the observer, at which the angles ADB, BDC have been measured.



On AB [Euclid III. 33] describe a segment containing an angle equal to that subtended by the objects A and B, and on BC describe another segment BDC, containing an angle equal to that subtended by the objects B and C, the point D where the two circumferences intersect, will evidently mark the station required. Should the two circles have the same centre, their circumferences must obviously coincide, and therefore every point in the containing Arc, will answer the conditions required, in which case the problem becomes indeterminate.

Example.—Let the three objects on shore ABC be fixed in position, and let the angle subtended at D by AB be equal to 50°, and the angle subtended by BC be equal to 40°; to find the point D by construction, subtract double the angle ADB from 180° and take half the remainder, equal 40°. Lay off this angle at A and B, the two lines forming the angles with AB will meet in E, the centre of a circle passing through ABD [Euclid III 20] again subtract double the angle BDC from 180°, and take half the remainder, equal to 50°. Lay off this angle at B and C; the two lines forming the angles with BC will meet in F, the centre of a circle passing through B, C and D. The point D, where the two circles intersect, marks the station required.—QED.



STONE QUARRIES IN THE NORTH WESTERN PROVINCES.

[The following four papers upon Stone Quarries are the result of a call made by the Government for information on the subject. They contain many valuable details in a matter which has hitherto received little attention; and though, in some respects, they are incomplete and imperfect; it is hoped that their publication may be the means of stimulating enquiry and of eliciting further information.]

REPORT ON THE STONE QUARRIES IN THE DISTRICT OF AGRA, BY MR. P. B. REID, DEPUTY COLLECTOR, DATED 17TH NOVEMBER 1846.

Locality and number of quarries.

Stone quarries exist in 3 pergunnahs of this district, viz., Futtehpore Seecree, Surheindee, and Furrah. Their locality and present number are as follows:

PERGUNNAH FUTTEHPORE.

In Qusbeh Futtehpore, -- -- --	11	Five on *milkee* lands, and six on *khalsa.*
In Mouzah Dahur, -- -- -- --	2	
In Mouzah Tejpore, -- -- -- --	3	*Maafee* village.
In Mouzah Goor-ke-Mundee, -- --	1	
In Mouzah Joutana, -- -- -- --	5	
In Mouzah Mundee Mirza Jan, --	1	
In Mouzah Bhurkoul, -- -- --	2	*Maafee* village.
Total, -- --	25	

PERGUNNAH SURHEINDEE.

In Mouzah Jugnair Bussye, -- --	13	
In Mouzah Tauntpore Ghuskutta, --	11	
In Mouzah Bhagour, -- -- -- --	4	
Total, -- --	28	

PERGUNNAH FURRAH.

In Mouzah Dhanowlee, -- -- --	8	
In Mouzah Nunwarah, -- -- -- --	8	
Total, --	16	

In all 69 quarries.

Specimens of stone.

Specimens of stone from the several quarries, labelled, and accompanied with lists, &c., have been forwarded to Mr. Middleton, Principal of the Agra College, as directed.

Proprietorship.

No correct information can be got from the canoongoes or their old *mouzeenahs*, as to the exact position of the former Government, in respect to these quarries.

Tax levied by native Government.

Same continued by our Government.

A tax, or toll of eight annas a month on each of the Futtehpore *khalsa* quarries, is said to have been levied on the parties working them, (those on *milkee* land have never paid a toll,) and this seems to have been continued by our Government, till the revised settlement, when the toll on the quarries, in common with other *rukoom-i-suwaee*, was taken off

by the Settlement Officer; but no reason for so doing is given in the settlement records. The sums credited to Government in the Collector's books for three years antecedent to the settlement are stated in the margin. From the quarries within the malgoozaree villages in the Futtehpore pergunnah, as well as from those in Surheindee and Furrah, Government seems never to have derived any benefit. The right of allowing stone to be quarried at these mouzahs has always been in the hands of the *zumeendars* or village proprietors, within the precincts of whose estates quarries have been formed. The rate of tax and manner of levying it appears to be regulated, as it always has been according to circumstances, and as suits the convenience of the engagers; in some places, eight annas a month per quarry is charged; in some, so much for working deserted quarries, and so much for opening new ones; and in others, (for instance at mouzah Tauntpore in Surheindee,) eight annas a month upon each *kodah* or pick-axe used in the quarry is charged. Such engagements with the zumeendars are entered into by the stone hewer or *sungturash*, or as they are commonly called chukkera, (chukkee maker,) of whom several families reside in the vicinity of the quarries, and keep the business among themselves without any limit of time, or defined boundaries. If a quarry be deserted by the original engager, the zumeendar has the power to let it to a fresh engager. In former years the zumeendars used to take an equivalent in stone for their own use instead of money; but this is now not adopted. The zumeendars are perhaps too poor now to enjoy the luxury of stone houses, as their fathers did: the prefer turning every thing into money.

When taken off.

1837-38, ...	40	0	0
1838-39, ...	7	0	0
1839-40, ...	40	3	0

None since.

Zumeendars' connection with quarries.

The annual income to the zumeendars in pergunnah Surheindee, calculated on an average of three years, is reckoned at Rs. 200, viz. Rs. 100 a year in mouzah Jugnair Bussye, and 100 in the other three villages. No similar returns are forthcoming for Futtehpore and Furrah.

Income to zumeendars in Surheindee.

Some quarries are worked for seven or eight years, others only for one season according to facility of quarrying, and the quality and quantity of stone dug.

How long quarries are worked.

As soon as the diggers reach the moist earth, or the water appears, they cease from digging; the maximum depth is about 20 cubits from the surface; but many quarries are given up long before the diggers go down so far, on account of the heavy expense of lifting up the stone from the quarry: yet it is allowed that the best stone is always found in the lower strata. From this it may be argued, that either the diggers have not energy enough, or their present means of quarrying are insufficient.

To what depth.

There are no assigned limits to a quarry. If two be working counterminous to each other, the space between each is divided by mutual consent. Should they be situated on the lands of two contiguous mouzahs, the intermediate boundary is the line of demarcation for each quarry.

Limits of quarries.

Nothing was recorded at the revised settlement relating to these quarries, excepting that the quantity of land, occupied by the hills or rocky eminences, where quarries are formed, was exempted from the *malgoozaree* or assessed area, and thrown into *minhaee*, the wording "*Arazee-i-koh*" (hilly land) being a distinct entry in the minhaee lists; for instance, in the papers of pergunnah Futtehpore the following entries appear under this head.

Quarry land how recorded at settlement.

	Beegahs.	*Biswahs.*
Qusbeh Futtehpore, 2nd Division, -- -- --	34	4
Ditto ditto, 3rd ditto, -- -- --	12	15
Ditto ditto, 4th ditto, -- -- --	51	5
Mouzah Joutanah, -- -- -- -- -- -- --	413	2
Ditto Goor-ke-Mundee, -- -- -- --	83	17
Ditto Mirzapore, -- -- -- -- -- --	12	8
Ditto Kurkoul and Tejpore, Maafee villages.		

Access to river.

The only means of access to the river from the several quarries in this district, is land carriage: either carts are employed to convey stone, or, when articles made can be rolled in the fashion of wheels, draught cattle (buffaloes chiefly) are used.

Roads.

The roads from the quarries to Agra are heavy and sandy, distressing the cattle and considerably increasing the expense of transportation. The expense of making an approach from the cart road to the mouth of the quarry on an eminence, is borne by the party working the quarry.

Pergunnah details.

The following points of information being diverse in their nature in each pergunnah, the peculiarities of each pergunnah are given under the pergunnah head, viz.

Quality of stone.

PERGUNNAH FUTTEHPORE.—The stone produced in the quarries of this pergunnah is considered of inferior quality to that got at the neighbouring quarries within the Bhurtpore territory at mouzah Puharpore, &c.; it is chiefly of the description called *lall puthur* (red stone,) brittle, not easily smoothened, and soon destroyed by nitre or salt, or the action of the atmosphere and rain. The Tejpore quarries yield a somewhat better kind, which is dearer than the rest. Very little of the Futtehpore stone is used for building purposes, such as beams, pillars or architraves, requiring to bear much weight; it is sometimes hewn into squares, for erecting rough walls with, instead of brick, or into cylinders for well bottoms, and other small articles of domestic consumption, which are hardly ever exported.

Articles made.

Where sent.

The only article made for exportation to foreign parts at the Futtehpore quarries, and in which the trade consists, is the chukkee or hand grinding mill. Several thousands are annually made and taken away to Lahore, Umritsur and various towns and marts in the North Western Provinces by the carrying merchant, who purchases from the beoparee or local trader, he (the local trader) having in the first instance purchased from the chukkera or stone-mason. The chukkera from time to time engages with the beoparee to supply him with so many chukkees, and receives advances of money accordingly. As a certain number are prepared, they are made over at the mouth of the quarry to the beoparee. On the arrival of the carrying merchant, he purchases from the beoparee, and makes his own arrangements for conveying away the chukkees; thus, three distinct parties are concerned in this trade—the stone hewer, the local trader, and the carrying or foreign merchant.

Parties engaged in stone trade.

Rates and prices.

The prevailing rate charged by the chukkera to the beoparee, is Rs. 20 for a hundred chukkees, (or 200 separate stones of the requisite circumference and thickness, each mill having an upper and nether stone,) at all the Futtehpore quarries, excepting at Tejpore, where, from the better description of stone used, it is 29 rupees per hundred. A further charge of 4 Rs.

a hundred is then made by the chukkera for cutting holes in the centre of each stone, to receive the spindle or handle for turning the mill. The common selling price paid by the carrying merchant is from 32 to 40 rupees a hundred. The beoparee thus derives a profit of from 7 to 8 rupees on a hundred chukkees, or about 30 rupees per cent. on his outlay, to cover interest of money, risk, and gain on trade. The expense of conveyance to the river side at Agra is from 10 to 12 rupees a hundred on carts, and from 6 to 7 rupees a hundred (about an anna a chukkee) if drawn by buffaloes, or bullocks, roller fashion.

The wholesale selling price of chukkees at Agra is from 48 to 50 rupees a hundred, or by retail from 8 to 12 annas each, thus giving a remunerative profit of from 3 to 5 rupees on a hundred chukkees, to the carrying merchant. Quality of stone and weight of chukkee influence the selling price very much.

Stonehewer's remuneration.

The chukkera's or stonehewer's remuneration cannot be so clearly ascertained. A head man or contractor for the quarry sometimes employs hired workmen, or he and the members of his family work the quarry and live upon their labor. It is supposed, however, that he gets about 3 annas a chukkee. A working man makes about one chukkee a day, including quarrying and all.

Modes of conveyance.

Chukkees conveyed in carts fetch a better price than those drawn by cattle, because by the latter mode the stone gets chipped, and is rendered rough and dirty. The process of rolling chukkees by means of draught cattle may be thus described: 8 or 10 stones are placed alongside of each other in a standing position, a piece of rounded wood or pole is passed through the centre holes, to the two ends of which transverse poles or shafts about six feet in length are attached; to these shafts a buffaloe is yoked by means of ropes, and draws the rolling mass behind him.

The chukkee, or handmill —how long it lasts—its general use.

A chukkee lasts from 3 to 10 years, according to the grinding it receives, and the hardness of the stone. One in daily use is renovated every two or three months, by making the grinding surface rough with a hammer and chisel. When the stones become thin and light by constant chiselling, they are laid aside and a new chukkee purchased. The chukkee is almost an indispensible piece of furniture in native house-keeping. It is met with in the great man's establishment, and seen in the poor man's hut. Every hamlet cottage containing a family has its chukkee to grind the corn for daily consumption, and if the village bride takes no other dowree to her husband, she must have her chukkee. The women of a family, whose duty it is to use the chukkee, love it exceedingly. The earliest sounds heard in the morning, in town or village, are those of the chukkee, and it is a certain indication of want of food in the house when the rustic's chukkee is silent; "*chukkee nuhee chultee*," is a common mode of expression among the poorer classes to denote extreme poverty. Hence the extensive use of stone in chukkee-making.

Bhurtpore contiguous quarries.

In connexion with the Futtehpore quarries, it may be of use to notice the neighbouring ones in the Bhurtpore territory, at the villages of Puharpore and Singowlee. The former village is eight coss from Futtehpore, and the latter about four.

Quality of stone.

The stone quarried at these two places (especially Puharpore) is of superior quality; it is extensively used in building, and taken to all parts of the country in various forms, both light and heavy. It is commonly divided into two kinds, the *bassee* (white or bamboo colored) and the *lall* or red stone. The *bassee puthur* is the better sort; it is more durable, bears

smoothening better, is easier worked, and is better in appearance than the *lall puthur.*"

Rajah's tax.

No quarrying is allowed without permission of the Rajah, and the tax paid to him by parties working the quarries is, at Puharpore: on white stone, 5 rupees 8 annas per 100 maunds; on red stone, 4 rupees 8 annas per ditto;—at Singowlée: on red stone, 5 rupees per 100 maunds; (no white.)

Sungturash's charge.

The charges of the *sungturash* besides the above Government tax paid by the purchaser are, at Puharpore, for white stone, 7 Rs. ½ anna per 100 maunds; for red stone, 5 rupees 8½ annas per do. do; and 4 annas per 100 maunds for loading stone on carts; at Singowlee for red stone, 6 rupees per 100 maunds.

Trade.

The sungturash shapes the stone roughly into the article the purchaser requires, (pillars, slabs, blocks, &c.,) and places it on carts furnished by the purchaser at the quarry's mouth, and his connexion with it ceases. The expense of transportation is regulated by the distance the stone has to travel, and by its bulk. On very heavy pieces, which require stronger and larger carts, and better cattle, the charge is from 25 to 30 rupees per 100 maunds; from Puharpore to Agra, on lighter materials from 17 to 19.

Measurement of stone to determine weight.

The weight of stone is determined by measurement, thus: 1 *mewaree guz*, (= 33 inches of an English yard,) in length, one-twentieth or 1 *biswah* of the same in width, and the same in thickness = 3 seers of red stone and 4½ seers of grey stone. By this cubic calculation, the measurement of blocks, slabs, &c. is adjusted.

Uses of stone.

Great quantities of stone from Bhurtpore are annually taken to Bindrabun and Muttra for the building of Hindoo temples, dwelling houses for the native gentry, ghauts, &c. A good deal is also brought into Agra, and thence, in the way of trade, taken by water to other places up and down the Jumna.

For the removal of very heavy stone, the purchasers sometimes are obliged to make up strong carts or trucks, and hire cattle to draw them.

Pergunnah Surheindee.—The quarries in this pergunnah yield both grey and red stone. All the grey is considered of one quality, and goes by the name of *sufaid puthur;* but the red is classified into *Taleca* and *Ravara.* The following building materials are made at these quarries.

Tham.—Pillars, or posts, circular or square, of sizes.

Putteea.—Flat oblong blocks or slabs used for architraves, lintels, for doorways, cornices, &c., according to thickness and dimensions; common size 7 feet long, 3½ feet wide, 2 inches thick.

Jael.—Narrow slabs for window shades, balconies and stairs; generally thin, and not more than a foot or 15 inches wide; better cleaned than the putteeas.

Chowkah.—Square or oblong flags used for flooring, roofing, &c.; the common dimensions being 5 feet long, 2 wide, and 1 or 1½ inch thick.

The sungturash's charge (or he who contracts for the supply to the purchaser,) at the quarries, 7 rupees per 100 maunds for grey stone, and 5 rupees per 100 maunds for red.

Chowkahs are mostly in demand for Agra, and these are purchased from the hewers on the spot from 1½ to 2 annas each, or from 2 rupees to 2 rupees 8 annas per score. Beoparees or dealers, generally contract for them at 10 rupees per 100 maunds, and allow the putwaree of the village ½ anna or so in the rupee for watching their interests.

Chowkahs sell at Agra from 6-8 to 7 rupees a score, or 45 to 50 rupees per 100 maunds by weight.

The cart hire from these quarries to Agra is from 15 to 18 rupees per 100 mds. A four-bullock cart conveys about 30 maunds. The selling price of Jugnair stone at Agra commonly is, for heavy articles, from 35 to 40 rupees per 100 maunds. In the rains, when supplies are stopped, it is higher. At Agra, many small articles of domestic use, such as platters, cups, water troughs, &c. are made of the Jugnair stone by the sungturashes, and sold in the bazars. Ornamental pillars, trellis work, for houses, &c. are also thus made, but none of these articles are ever made at the quarries.

On an average of three years, the quantity of stone from pergunnah Surheindee brought into the city of Agra, is about 5 thousand maunds a year, and about 6 thousand maunds taken to Muttra.

Many foreign purchasers do not resort to these quarries; the trade seems to be confined to the city of Agra. Carrying merchants take large quantities of slabs from Agra to Dehlie by water, and to the Dooab and Trans-Gangetic Provinces of Rohilcund by carts.

PERGUNNAH FURRAH.—The red stone is alone found in the quarries within this pergunnah. The articles made from it, and chiefly for local use, (*i. e.* in the district,) consist of the chukkee, or hand mill; the koloo, or oil and sugar mill; the *khandeh* or *ent*, or squares used for bricks, for wells, walls, &c.

But the chukkee is the principal article made. The sungturash or chukkera's charge at the quarry's mouth is 20 rupees per 100 as in Futtehpore. He sells at 25 or 26 rupees per 100. Oil or sugar mills are from 12 to 15 rupees each: *ent*, or squares, at 8 annas a hundred, in tale.

The distance from Dhanowlee to Gow Ghaut on the Jumna (10 miles west of Agra) is five coss, from Nimmiah seven coss.

Chukkees are commonly rolled to this ghaut by buffaloes, or bullocks as above described; all other articles are conveyed in carts. The selling prices at Gow Ghaut are for chukkees,—33 rupees per hundred; for koloos,—18 to 20 rupees each; for khandeh,—5 rupees per hundred.

Chukkees from the Nimmiah quarries are about 2 rupees per 100 higher than those of Dhanowlee, on account of the greater distance from the ghaut than Dhanowlee.

REPORT BY W. E. MONEY, ESQ., COLLECTOR OF ZILLAH MIRZAPORE, UPON THE STONE QUARRIES IN THAT DISTRICT.

From W. E. MONEY, ESQ., *Collector of Mirzapore, to* E. P. SMITH, ESQ., *Commissioner of Revenue, 5th Division, Ghazeepore, No. 211.*

SIR,

With reference to the instructions contained in the minute by the Lieutenant-Governor, North Western Provinces, dated 30th January, and received with your letter No. 52 of 9th March, relating to the stone *mehals* of this district, I have the honor to submit the following information, which I trust will answer the desired purpose.

2.—With the view of exhibiting the amount of revenue derived by Government from the stone mehals, I have the honor to subjoin a statement of the yearly amount realized since the separation of this district from that of Benares, under the operation of the duties established by Regulation II. of 1800.

Date.	Jumma realized.			
	Rs.	A.	P.	
From Nov. 1830 to April 1831, Kham Tehseel, -- -- --	22,131	6	2	*
„ May 1831 to April 1832, ditto, -- -- -- -- --	29,823	0	1	
„ May 1832 to April 1833, ditto, -- -- -- -- --	33,587	15	4	
„ May 1833 to April 1834, ditto, -- -- -- -- --	19,372	1	0	
„ May 1834 to 14th March 1835, ditto, -- -- -- --	17,800	9	4	
„ 15th March 1835, to 15th ditto 1836, Rugber Dial, &c., farmers, -- -- -- -- -- -- -- -- --	32,001	0	0	
„ 16th ditto 1836 to 15th ditto 1837, ditto, -- -- --	32,001	0	0	
„ 16th ditto 1837 to 15th ditto 1838, ditto, -- -- --	32,001	0	0	
„ 16th ditto 1838 to 15th ditto 1839, ditto, -- -- --	32,001	0	0	
„ 16th ditto 1839 to 15th ditto 1840, Kham, -- -- --	24,146	10	6	
„ 16th ditto 1840 to 15th ditto 1841, Mr. Menzis, farmer,	28,500	0	0	
„ 16th ditto 1841 to 15th ditto 1842, ditto, -- -- --	28,500	0	0	
„ 16th ditto 1842 to 15th ditto 1843, ditto, -- -- --	28,500	0	0	
„ 16th ditto 1843 to 15th ditto 1844, Prag Dutt Doobey, &c., supoordars, -- -- -- -- -- -- -- -- --	28,500	0	0	
„ 16th ditto 1844 to 15th ditto 1845, ditto, -- -- --	28,500	0	0	
„ 16th ditto 1845 to 15th ditto 1846, Prag Dutt Doobey, &c., farmers, -- -- -- -- -- -- -- -- --	29,500	0	0	

3.—For the first four years the mehals were held under kham management, and the duties collected by Government servants, as prescribed by the above Regulation; but in March 1835, they were leased out to farmers, and with the exception of one year, viz. 1839-40, the same plan has been followed up to the present time.

4.—There can be no doubt that for many years subsequent to the promulgation of Regulation II. of 1800, such was the demand for stone from these mehals that no difficulty was experienced in levying the prescribed duties in the usual legitimate manner; but of late years, the demand from other quarters has so much decreased, that the farmers, to enable themselves to pay their jumma and realize a small profit, have to depend entirely on the monopoly afforded them by their lease, and act precisely in the manner described in the 5th, 6th and 7th paragraphs of the Lieutenant-Governor's minute.

5.—The decrease has no doubt been caused by the existence of duty-free quarries in other parts of the country; and that any demand at all should exist under such heavy prohibitory duties as obtained in these mehals, can only be attributed to the vicinity of the quarries to so many populous cities, where a certain supply must always be kept up.

6.—The prohibitory nature of the duties now levied are particularly felt in the Chunar division, where, under the operation of Regulation II. of 1800, the duties are considerably higher than in Mirzapore. In the latter division cut stone *of all sizes* pays an uniform duty of 2 annas and 6 pie per cubic foot, while in the former the charge for small stones only is 2 annas and 8 pie per cubic foot. If a stone measures 4 cubic feet the duty is 4 annas, and for all measuring 5 feet and upwards, the duties are no less than 5 annas per foot.

7.—The reason assigned for the difference is, that the stone of Chunar is of a finer quality and texture than that of Mirzapore, and also that the quarries being nearer the river, heavy stones can be transported at a less cost, and are therefore better able to bear an increased rate of duty; but the effect has been, that, excepting

* Cost of establishment amounted to 152 rupees a month.

for expensive and ornamental works, where price is no object, no one will take stones from Chunar at a duty of 5 annas per foot, in preference to those of Mirzapore at half the cost.

8.—The present farmers, who have taken a five years' lease from March 1845, are four stone merchants of some capital, who share the profits and loss in equal proportions, and do not appear to be connected with any other parties. They modify the Government duty considerably to the merchants, who keep on terms with them, and with those who do not, the enforcement of the letter of Regulation II. of 1800, is sufficient to prevent opposition.

9.—By the regulation, the duties upon stone are leviable before they are removed from the quarry, but the beoparee, who is already under advance to his muhajan, and cannot realize the price of the stone till it is sold and delivered, has not the means of paying, and is therefore constrained to keep on terms with the farmer, who, by the enforcement of the regulation, can put a stop to his trade altogether.

10.—It is this power, which enables the farmer to create an almost exclusive monopoly of his own, which he effects to the full extent of his means. He constrains the beoparees to sell him stone at the kutcha rates as far as he has the means of purchasing, and only allows them to remove what he himself is unable to take.

11.—In return for their compliance, he allows the stone to be taken to the different chowkees on the banks of the river, where they are prepared for export; and the duties, which to friendly parties are much modified, are not levied till the stones are sold and removed.

12.—The amount of duty remitted is not the same in all cases, but the usual extent is from 10 to 12 per cent. on common stone. On *kolhoos*, or sugar mills, it is from 15 to 17 per cent. The latter are quarried throughout the year, but only exported in the rains, at which time the duties are paid; were they levied at the quarry, as the regulation authorizes, the trade in this description of stone would be stopped altogether.

13.—European stone-cutters and large capitalists, who deal in stone of an expensive kind, are not included in the above compromise, but pay the full duties authorized by the regulation. They however find it their interest to keep on terms with the farmers, and by this means enjoy the privilege of not paying duty till the stone is removed from their working yards.

14.—The only way to put an end to this monopoly, provided the farming system is continued, would be to lease out the mehal in small portions to different parties, each portion to comprise a certain number of *mouzahs*, compactly situated, with the limits of each *elaquah* properly defined.

15.—This would destroy the power of the present monopolists, and greatly benefit the trade, as the competition between the different small farmers would cause them to reduce their profits to the lowest possible standard.

16.—It was formerly customary, when a beoparee wanted to open a new quarry, for him to present a *durkhast* to that effect to the Collector, who gave him written authority to do so, but this custom has long been in disuse, and he now selects his own locality without consulting any one save the muhajan, who advances him the money to begin.

17.—The selection of a piece of ground for a new quarry is a matter of great importance, and attended with much uncertainty. Sometimes a good situation is found near the surface which can be worked with great profit and facility, whilst in other places the expense and difficulty of removing the superincumbent strata before good stone is reached, causes the whole work to be abandoned with considerable loss.

18.—If the stratum turns out a good one, the beoparee has no difficulty in clearing his advance and working his quarry with considerable profit, but his means do not allow him to go to any considerable depth, and when he has exhausted all the stone that can easiest be got at, he usually seeks for a new locality. The depth of the quarries varies from 8 to 25 feet according to the value of the stone, and the means of those who work it.

19.—Although the quarry is deserted for a new one, and may be unoccupied for a succession of years, the beoparee still retains a right of property over it, and if a larger capitalist, with means of working to a greater depth, wishes to re-open the quarry, he cannot do so, without first purchasing the rights of the original proprietor.

20.—To show at a glance the injurious nature of the present excessive rate of duties on the stone trade, I beg leave to subjoin a statement of the cost and charges upon a description of stone in common use, by which it will be observed, that the duties are 25 per cent. greater than all the other expenses put together.

Cost of 2 *bhotes*, each measuring 6 feet long, 2 feet broad and 3 inches thick.

	Rs.	A.	P.
Stone-cutter's remuneration, -- -- -- -- --	0	4	0
Hackery hire, -- -- -- -- -- -- -- -- --	0	8	0
Government duty 2½ annas per cubic foot, -- --	0	15	0
Total, -- --	1	11	0

21.—The duty for the same stone in Chunar is 1 rupee, and yet they are sold with difficulty at 1-12-0, and sometimes for less when a good reduction of duty can be obtained from the farmer.

22.—I subjoin a list of several small articles not enumerated in Regulation II. of 1800, on which a separate rate of duty has been fixed for the whole mehal. These articles, most of which are in considerable demand, do not appear to be included in the compromise alluded to in paragraph 9, 10, 11 and 12, of this report, but it is not unusual for the farmer to sub-let the duties on some of them for a fixed amount, leaving the sub-farmer, who thus becomes a monopolist of the article specified, to make his own collections and arrangements.

Name.	Duty.			
	Rs.	A.	P.	
Mulookee or Koondee, ...	0	14	0	Per hundred.
Punjeebbeeah, ...	1	12	0	ditto.
Thurceah, ...	2	10	0	ditto.
Kutorah, small, ...	1	12	0	ditto.
Chowkah, 1st quality, ...	2	3	0	ditto.
Ditto, 2nd ditto, ...	1	12	0	ditto.
Kutorah, large, ...	3	8	0	ditto.
Ditto, middling, ...	1	5	0	ditto.
Chundrowtah, ...	0	14	0	ditto.
Hoorsah,...	0	7	0	ditto.

23.—In compliance with the instructions conveyed in the 15th paragraph of the Lieutenant-Governor's minute, I have the honor to forward a register of 283 quarries at present open, and of 894 closed, according to the form prescribed. They are situated in 63 mehals, comprising 75 mouzahs, paying a Government revenue of Rs. 70,645 per annum, but the zemindars are precluded by Regulation II. of 1800 from exercising any control over them. * * *

Extract of a Report from E. H. C. MONCKTON, Esq., *Officiating Deputy Collector of Allahabad, No. 373, dated 2nd April 1846.*

4.—The stone quarries state, that there are ten or twelve quarries in mouzah Purtabpoor, pergunnah Barra, of which only two are worked by merchants. The tehseeldar states four as the total number worked. There is no cart road, but only one fit for foot passengers. The distance is variously stated at from 25 jureebs to half a koss from the Jumna, to which the stone is carried by men, who make it their livelihood. The stones are not weighed at the pit, but sets of eight, twelve and sixteen men are employed teekah to carry sets of four according to their estimated weight to the river. Thus, if they are small, eight men carry them, if a size larger, twelve, and if still larger, sixteen. One stone only is carried at a time from the pit to the river, and put on board the boat. The largest stone known to have been dug of late years was in the Banda zillah; it weighed 15 maunds, was 10 feet long and 1½ feet square, and required sixty-four men to carry it. The heaviest stones raised here weigh 14 maunds.

5.—There are three sorts of stones found in the Allahabad district, two of which find their way to market in a manufactured form. The former are termed, *golabee* and *sufaid*—the latter, *dhoka*, which is used in the lump as foundations for walls. The two former are used indiscriminately for khumbas, puttees, burgas, hoorsas, hoolsees, mehras, lohras, sils, koondees, panchoras, sung farashes and kolhoos. The white stone is alone used for chukkees, jantas, and khurruls, as being of a harder nature; no stone is sold in the neighbourhood of the quarry or river, but is brought to Allahabad, which is the only mart for it; at present it is therefore impossible to compare the relative value with that quarried at Mirzapore.

6.—The terms janta, chukkee, hoorsa, selee, dhooka, puttea, kolhoo, khumba, mentioned in Section 82, Regulation XXII. of 1795, appear to correspond with those in use in the market here, while chowka, dassa, awbboot, boojowtee, nulbuddrow, khoonth, either seem local terms proper to Mirzapore, or else constitute articles not in the market here. The head workman in the quarry receives 9 rupees, the rest from 6 to 8 rupees a month.

7.—The price in the Allahabad market is as follows:—At Bulloa Ghat 100 maunds of either sort is landed in the unwrought mass at 20 rupees, thus, it costs 16 rupees to cut, carry and load it on board the boats at Purtabpore on the Jumna, 3 rupees boat hire to Bulloa Ghat at Allahabad, and 1 rupee for landing it, making in all 20 rupees, and is sold in the market at from 22 to 25 rupees the 100 maunds. The dhoka is sold at 5 rupees, or less, the 100 maunds; its sole use is for the foundations of buildings, and is found to be cheaper than bricks for this purpose. Khumbas from 3 to 7 feet in length, and 6 inches to 1 foot square sell for from 22 to 25 rupees the 100 maunds, and are landed for 20 rupees. Bundga or burga from 1½ to 4 feet in length, and from 10 inches to 1 foot in breadth, and 2 inches thick sell for 3 rupees 8 annas the 100 square feet. Of puttees for roofing or paving rooms from 4 to 10 feet long, 16 to 18 inches broad, and 3 to 5 inches thick, the price is from 22 to 25 rupees per 100 maunds. Of mehrah, used for paving court-yards, or for cornices, or supports at the top of khumbas, from 4 to 6 feet long, 2½ to 3 feet broad, and 3 to 5 inches thick, the price is from 22 to 25 rupees per 100 maunds.

Chukkee—ready for use, 1 rupee.

Janta—ditto, 12 annas.

Hoorsa—used by Hindoos for preparing and rolling their bread on a wooden roller, from 1 anna 9 pie to 2 annas 3 pie.

Hoolsee—a small circular stone for pounding.

Chundun—used for tilluk, half an anna.

Lohra—the muller for rubbing on the sil from 10 to 12 inches long, 1 anna.

Sil—from 8 inches to 2 feet long, from 1 anna to 4 annas.

Sung furash—or weights for keeping down carpets or placing against doors are sold in sets of 4, for from $1\frac{1}{2}$ to 2 rupees the set.

Khoordee—or stone saucer, from 3 to 5 inches in diameter, from 1 anna 9 pie to 2 annas.

Khurul—or pestle and mortar, from 6 inches to 13 inches in length, from 8 annas to 1 rupee.

Punchora—or stones for supporting legs of charpoys and made to hold water, 4 of which are sold in a set varying from 6 inches to a foot in diameter, at from 1 to 2 rupees 4 annas the set.

8.—The fort of Allahabad and other old buildings in the city bear testimony to the durable and excellent qualities of the *sufaid* and *golabee* stone for buildings. One sort, called dhoosur, is decidedly bad for these purposes, and is speedily destroyed by salt, as would appear from the rapid destruction taking place in the magnificent Baolee attached to Sultan Khoosroo's garden.

9.—The only places that seem ever to have been supplied from these quarries beyond their immediate neighbourhood for agricultural purposes, (as chukkees, kolhoos, &c.,) are Lucknow, Cawnpore, Humeerpore, and Allahabad.* Khumbas, &c. were sent to Cawnpore and Humeerpore for the use of Government only, when the buildings in cantonments were being constructed; those sent to Lucknow were of great size and required for some bridge. Since then the only place which has been supplied from these mehals is Allahabad.

10.—No competition, notwithstanding the duty, can take place with Mirzapore for several reasons. The first is, that the stone of that place is better to the extent of 5 rupees in every hundred maunds. The Mirzapore stone is found good at the surface, whereas at Purtabpore it is found good only at an average depth of 25 feet. The earth is first dug out to the depth of from 12 to 14 feet, the bad hard stone, called dhoka, is then blown away with gunpowder, till the golabee and sufaid make their appearance, and after all it is a matter of chance and good luck if it turns out of a good quality and fit to be worked. The boat hire from Purtabpore to Allahabad is 3 rupees, whereas from Mirzapore to Allahabad it is from 10 to 16 rupees the 100 maunds, which difference would prevent the Mirzapore stone from finding a market at Allahabad, whereas the Mirzapore stone being of better quality and found on the spot at a cheap rate, notwithstanding the duty, would prevent the stone of this district being sent there or any where below it. The quarriers assert that, if the duty at Mirzapore were removed, and that they were to quarry at Mirzapore, they could not bring 100 maunds to Allahabad, at a less rate than 30 rupees, without profit, whereas they sell their own stone now at from 22 to 25 rupees the 100 maunds, taking a profit

* The quarries at Purtabpore have been closed for the last six months, owing to the great depth the stone is found at; and the merchants procure their supplies from the Bundlecund districts, about two miles further off, whence it is procured at the same cost, but with this difference that here they have to make advances for quarrying with the risk of its turning out bad, whereas there they get it good without trouble and ready quarried.

of from 2 to 5 rupees. Cawnpore is apparently more or less supplied from Mirzapore; in this way, the quality of stone being superior and the articles of consumption small and few, they are placed on empty return boats and are found to be more profitable, even though brought a greater distance than the inferior stone of Allahabad. Burgas, however, are sent to Cawnpore, viâ Allahabad, from Banda, at a cost of 12 rupees per hundred.

11.—Having answered all the queries contained in the above letter regarding the stone mehals in pergunnah Barra, and it being evident from the minute of the Hon'ble the Lieutenant-Governor regarding those in Mirzapore, that all the information possible on this subject should be collected, I have deemed it my duty to make enquiries regarding the stone found in other pergunnahs of this zillah, and beg to subjoin what I have been able to ascertain on the subject.

12.—Stone is found in several villages immediately on the banks of the Jumna in pergunnah Atherbun, and in pergunnahs Arail and Khyragurh, at distances varying from 1½ to 15 koss from the Ganges.

13.—The zemindars do not seem to exercise any right in the mehals in these pergunnahs, and the Government, either former or present, have not done so. The country people dig out the stone as they require it. It is mostly of inferior quality, and is not worked by the stone merchants. If any good pieces are found, they are made into chukkees and jantas, and sold in the neighbourhood. The only approximation to an exercise of right of possession seems to have been when Lieutenant Sharp, about 7 years back, blew up and carried away some stone from mouzah Teekur, pergunnah Arail, when Mussumat Oleea Begum complained to Mr. Montgomery, who referred her to the Civil Court, but it does not appear that she thought it worth while to go there; however, Lieutenant Sharp paid 4 rupees for every 100 maunds he removed. It is supposed that, though the stone at present found in this pergunnah is not good, yet by digging deep a better quality would be found. The stone in mouzahs Payagpoor, Ramgurwa, and Rajapoor, pergunnah Khyragurh, is reported the best in that pergunnah, and at the same time nearest the Ganges, to which a good cart road leads.

14.—The names given by the people to the different sorts are as follows:—In pergunnah Khyragurh—doodheea, bullooa, and kukura. The doodheea is found pretty good after digging through five yards of bad stone; the bullooa is of bad quality, and is used chiefly for walls in the lump; the kukura is also pretty good, and is found three yards deep, of tolerable quality. The doodheea and kukura are made into chukkees and jantas. In pergunnah Arail—doodheea, teleea, dhoosur, and choorba. These, according to their quality, are made into chukkees and jantas. In pergunnah Atherbun—doodheea, mutteea, burwah, and a sort of stone with red streaks without any particular name, not used. If any good stones are found, they are made into chukkees and jantas. The stone is reported as inferior, and not generally fit for building purposes.

15.—Though there are no means of ascertaining the exact value of stone at the quarry, as none is sold there, I have endeavored to ascertain the cost of digging it, which is as follows; eight men can dig 100 maunds of stone of all sizes up to 10 maunds in weight, at a cost of about Rs. 10; if the pieces are of larger size, say 20 maunds each, taking five stones to the 100 maunds, the cost will be about Rs. 15; if large, the same rates, (*i. e.*, 16 rupees to the 100 maunds,) still hold good. Eight men carry four stones weighing about 4 maunds each, *i. e.*, 16 maunds in all, to the river, and place them on board the boats at a cost of one rupee, which would make

about 6 rupees for every 100 maunds. If the four stones weighed 6 maunds each, it would require twelve men at a cost of 1 rupee 8 annas, or about the same price, *i. e.*, 6 rupees per 100 maunds, and so on in proportion to the size.

The very small lumps are carried by coolies on their heads, at a cost of about two annas for 16 maunds.

Burgas are carried on bullocks at a fixed price of 1 rupee 12 annas per 100 pieces.

Extract from a report of H. ROSE, Esq., *Collector of Banda, No. 191, dated 27th May 1846.*

2.—I have the honor to forward a register (marked A.) of the stone quarries in this district, prepared according to the form recommended in the minute of the Lieutenant-Governor; I forward also a similar register (marked B.) regarding the iron mines.

3.—The quarries in Banda, are on the same footing as those in Allahabad and Agra, "where the quarries are left entirely to the zemindars, the Government asserting no claim to the stones and levying no duty upon them."

4.—I have forwarded to your address by dâk banghy specimens of the different stones produced in the district, with numbers corresponding with those in the register. Two specimens of white stone common in this district are forwarded; these are not numbered nor entered in the register, because that species of stone is not turned to any use.

5.—I forward also a species of lime-stone which is found in the village of Kootla, in the foreign territory on the border of this district, and from which lime, said to be of very superior quality, is made in the village of Goorrampore, pergunnah Buddowssa. The Settlement Officer alluded to this circumstance in page 52 of his Settlement Report, where he says: "at Goorrampore, in Buddowssa, lime is manufactured to a large extent, and is exported to all the large stations and to Lucknow."

6.—The Rajah of Patur Kutchar, to whom the village of Kootla belongs, charges for the stone one pice per maund, and pays to the zemindars of Goorrampore two dumrees per maund for the right of way through their estate.

7.—The stone is converted into lime on the area of Goorrampore, and the manufacturers pay to the zemindars of Goorrampore from 4 annas to 10 annas per kiln, according to its size. The lime is sold on the spot to beoparees, who export it to different parts of the country. Four maunds of the best lime at Goorrampore are bought for one rupee.

APPENDIX A.

Register of Stone Quarries in the District of Banda.

1.	2.	3.	4.	5.	6.	7.	8.	9.
Number in List.	*Name of Mouzah.*	*Number of quarries in the Mouzah.*	*Name of owner.*	*Time that the quarry has been worked.*	*Quality of stone.*	*Quantity or value of stone raised in preceding year.*	*Terms of agreement with the farmer.*	REMARKS.
					PERGUNNAH	BUDDOWSSA.		
1	Rowlee.	1 Quarry.	Zemindars of the Mouzah.	From time immemorial.	Doonga and Bunsee. The first is the best quality.	Value said to average less than 200 per annum.	The proprietors of the village levy 1 rupee 4 annas per annum from each man who works in the quarry.	Mills and grinding stones, &c. are made from the stone, called *Doonga*, and flags are hewn out of the stone called *Bunsee*.
2	Goonda.	1 ditto.	Ditto.	Ditto.	Ditto.	100 rupees.	Ditto.	The same as No. 1.
3	Sidapoor.	3 Quarries.	Busawun and others, Zemindars of the Mouzah.	Since 20 twenty years.	Burooa, grey colour.	15 rupees.	The proprietors of the mouzah levy 2 rupees per annum from each man who works in the quarries.	Flags, pillars and ornamental arches, &c. of buildings are made from the stones raised from these quarries.
					PERGUNNAH	TIROHAN.		
4	Mundyan Bunwaree.	2 Quarries.	Nirbhyram and others, Zemindars of the Mouzah.	Previous to the accession of the British Government.	Doodhcea, red colour.	50 rupees.	.. ..	Various sorts of vessels are made from this stone. The *chumar* inhabitants of the village quarry, and the zemindars charge them nothing.
5	Bhounree.	1 ditto.	Buhoree Shew Golam and others, Zemindars of the Mouzah.	Since 3 years.	Ditto ditto.	30 rupees.	.. ..	The proprietors used to levy 2 rupees per annum from each individual who worked in the quarry. The quarry is not worked at present; stone of the same kind as No. 4.

1.	2.	3.	4.	5.	6.	7.	8.	9.
Number in List.	*Name of Mouzah.*	*Number of quarries in the Mouzah.*	*Name of owner.*	*Time that the quarry has been worked.*	*Quality of stone.*	*Quantity or value of stone raised in preceding year.*	*Terms of agreement with the farmer.*	REMARKS.
					PERGUNNAH TIROHAN.			
6	Koolgudhya.	1 Quarry.	Bhoop Sing and others, Zemindars of the Mouzah.	Since 15 years.	Burroon, grey.	50 rupees.	The proprietors of the mouzah levy 2 rupees per annum from each man who works in the quarries.	The proprietors used to levy 2 rupees per annum from each individual who worked in the quarry. The quarry is not worked at present. The same as No. 3.
7	Buryaree, kulan.	3 ditto.	Ram Ruttun and others, Zemindars of the Mouzah.	Since 20 years.	Musra and Lall.	Not known.	The proprietors levy 4 rupees 4 annas per annum from every person who works in the two quarries on the level ground, and 2 rupees from those who work the quarry on the hill.	There are 3 quarries in this village, two in the plains and one on a hill. The red stone *(lall)* is produced in the quarries on the plain, and the white stone *(musra)* is hewn from the quarry on the hill.
					PERGUNNAH CHIBOO.			
8	Purdawan.	5 ditto.	Nund Lall and Bhowanee, Zemindars of the Mouzah.	Since 10 years.	Lall.	49 rupees.	These quarries were let in farm last year for 49 rupees.	There are 4 quarries at present. Flags are made from the stone raised from these quarries. They are let this year for 56 rupees, there being a slight difference in the quality of this stone and lall, No. 7.
9	Mutteepoor, malee.	1 ditto.	Bhugwant, Zemindar of the Mouzah.	Since years.	12 Lall Buroha.	It was not worked last year.	The proprietors levy 4 rupees per annum from every person who works in the quarry.	The stones raised from this quarry are used as substitutes for bricks in constructing walls of buildings.

APPENDIX B.

Register of Iron mines in the district of Banda.

1.	2.	3.	4.	5.	6.	7.	8.	9.
Number in List.	*Name of Mouzah.*	*Number of quarries in the Mouzah.*	*Name of owner.*	*Time that the quarry has been worked.*	*Quality of stone.*	*Quantity or value of stone raised in preceding year.*	*Terms of agreement with the farmer.*	REMARKS.
					PERGUNNAH TIROHAN.			
1.	Deoree muafee.	1 Iron mine, and 7 *bhuttees* or forges.	Girdharee Doss, muafeedar of the mouzah.	Since 7 years.	Iron ore.	Not known.	The muafeedar levies a duty of 4 Rs. per annum for every furnace worked in the village.	The iron made in this village is annually exported to the districts beyond the Ganges.
2.	Rujboan.	1 Iron mine, and 42 *bhuttees* or forges.	Gungapurshad and Rampurshad, zemindars of the mouzah.	Previous to the accession of the British Government.	Ditto.	Ditto.	The proprietors of the village levy a duty of 5 Rs. per annum for every furnace in the village.	Ditto ditto.
3.	Goburhye.	1 Iron mine, and 17 *bhuttees* or forges.	Doorga, zemindar of the mouzah.	Ditto ditto.	Ditto.	Ditto.	The proprietors of the village levy a duty of 5 Rs. per annum for every furnace in the village.	Ditto ditto.
4.	Nihee.	1 Iron mine, and 10 *bhuttees* or forges.	Bhowaneedeen and others, zemindars of the mouzah.	Ditto ditto.	Ditto.	Ditto.	The proprietors levy a duty of 6 Rs. per annum for every furnace worked in the village.	Ditto ditto.

DESCRIPTION

Of the specimens of Stone common in Agra, Allahabad, Banda, and Mirzapoor, by J. Middleton, Esq., F. G. S.

On receiving the orders of Government to examine and report upon the capabilities of the stone used, or supposed fit, for building in these Provinces, it became necessary for me to consider what properties are most suited to ensure durability in stone, or the converse. The question has been often discussed by others; and though with reference to sandstone, the order which I have chiefly to examine, I have no authorities within reach, I am in no doubt about the general conclusions arrived at. In addition to this, I felt desirous of adding such information as might be interesting or useful in a scientific point of view. Amongst the qualities that are most essential to the durability of sandstone, exposed to atmospheric influence, are to be ranked compactness and uniformity of structural arrangement and strength of molecular constitution. Amongst the properties which have an opposite tendency, may be ranked the presence of peroxide of iron, the red colouring water of our sandstones. Wherever such stone is used, the evil influence of this substance soon manifests itself, producing disintegration of the surface of the stone. In the Agra College, during the rains—for it is then that the destructive activity of iron is most conspicuous—pinches and handsful of red, almost impalpable, powder are constantly falling from the roof. The palace in the Fort at Agra, especially the eastern front, affords striking evidence of the same destructive influence, the ornamental traccry being there almost entirely obliterated. Similar defacement is likewise observable on the elaborately decorated buildings at Futtehpoor Seikree; and, what is still more lamentable, that singularly beautiful and unique structure, the Quotab Minar at Dehlie, begins to manifest similar symptoms of incipient disease. Around the inner margins of the upper galleries, where rain-water lodges, exfoliation has begun, and scales of the stone may be stript off and pulverized between the finger and thumb; a ribband of some cement impermeable to water, might serve to retard the process of decay.

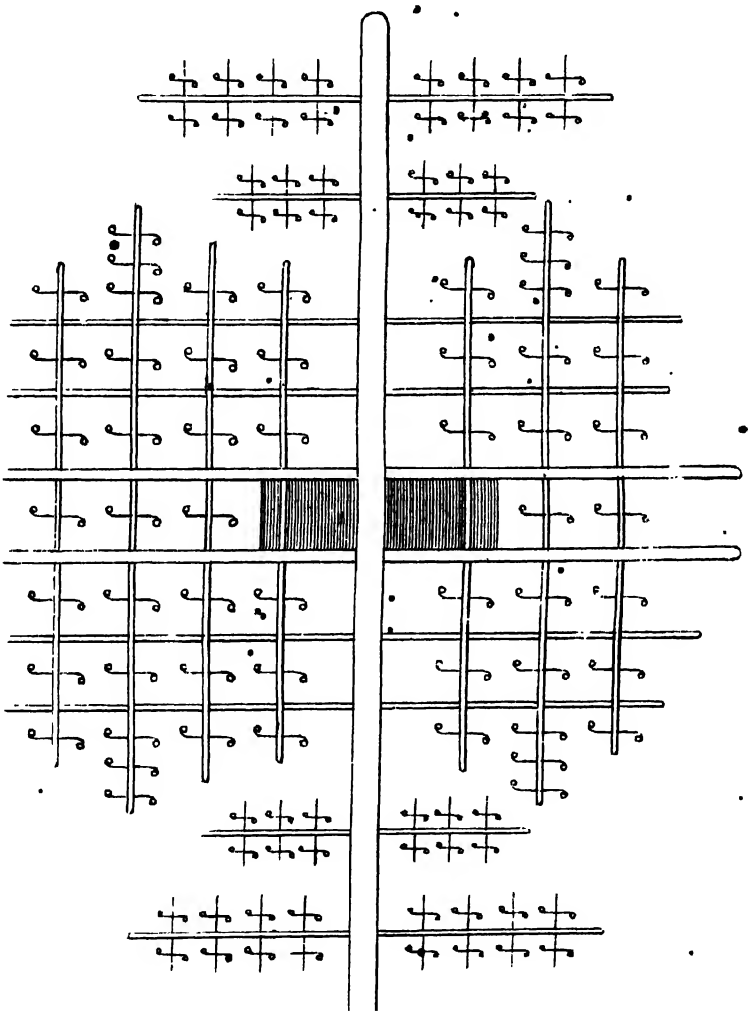
Another cause of decay in stones is ready absorption of water, which, when imbibed, by constantly expanding and contracting through influence of temperature, tends to unsettle or overthrow the molecular arrangement of the stones. In general, this element of destruction seems to co-operate with that considered in the last paragraph, so far at least as disintegration of surface goes.

In order to test the qualities of stones in the respects just adverted to, it became necessary to analyze them, or representatives of groups of them, accurately; and they being mostly silicious, a steel mortar became indispensable. With this I have been unable to provide myself, Native and European workmen, though undertaking it in turn, having alike failed in making one; and as the report on the quarries will wait for me no longer, this notice appears deficient in at least one important respect.

In ascertaining the absorbing capacity of the stone, the specimens operated upon, which were mostly small, as will be seen from the weighings, were all steeped at some distance under water for 48 hours. The period seemed, as proved by experiments performed with that view, to be sufficient for saturation. In the computations, the water displaced in grains troy is taken as the unit.

There is always considerable doubt attached to results from experiments performed to test the cohesive force of stones, i. e. resistance of stones to crushing pressure;

Arrangement for moving large Masses of Stone.



and although by care that the specimens operated upon were exactly of the same size and condition, and faithful representatives of the rock, also that the applications of the crushing force were always in the same direction with reference to the plane of stratification, such doubt might be minimized; yet the same care in placing the stones in the building could not be carried out, and the practical bearing of the experiments is therefore but small. It may be safely admitted, moreover, that, with reference to the stones now under notice, if they fail, it will not be through defect of power to resist pressure; and I have not on these grounds thought it necessary to expose the specimens to tests of this nature.

I have divided and arranged the rocks in series, according to the localities in which they are found. The tabular statements give the results of experiments, and the preparatory observations are descriptive of the appearances, &c., of the stone.

The arrangement by which large masses of stone are moved from place to place, is represented in the plate annexed to this note. It was sent to me by Mr. E. H. C. Monckton, from Allahabad, together with a description given below;* and as I have myself seen it employed elsewhere, can bear witness to its efficiency.

I have not taken the weights, directly, of the large specimens sent me, as no useful comparison could, without expense and waste of time, be made of the results; the specimens being, with exception of the Agra and Bhurtpore ones, of different sizes, and though intended to be cubes, yet being far from accurately so. There is, however, sufficient data in the tables for computing the weights, bearing in mind that a cubic inch of water at 4° centegrade weighs 252·962 grains, and that the density of water at 4° : density at 30°† : : 1 : 99,599. The computations have been made, and appear in the tables.

It is proper to observe that information derived from facts calculated to give direction to my enquiries and completeness to their results, was almost totally wanting to me. It is usual in Europe, when stones of good quality are required for the erection of expensive buildings, as lately, in the case of the British houses of Parliament, first to seek out proof of durability as afforded by existing ones, and then to determine the constitution of the material of which they are composed. This mode of proceeding is obviously necessary to give immediate practical value to such enquiries. If, however, the following results be in so far defective, they, it is to be hoped, still have a value independent of this, and will, moreover, be ready for practical application, when such may be necessary.

Allahabad Rocks.

Arail series.—No. 1.—"Doodheea" of the miners, and marked in my specimens as "4th sort," is a coarse crystalline quartzose sandstone.

* As the facility with which large masses of stone are moved, without mechanical aid, in these and other quarries, may not be generally known, and as the method adopted may aid in forming a solution of the difficulty in accounting for the construction of the pyramids, and other ancient buildings, I have much pleasure in subjoining it. A large stone is fastened securely on each side to two long and strong poles or beams, which extend a considerable distance in advance, and behind it; on these are again bound cross pieces, and on these other short cross pieces, to which the bearers apply their shoulders as in carrying a palkee. The poles are prolonged by additional ones being tied on, and the cross pieces extend according to the weight of the stone. If very weighty, in addition to the poles lengthways, others are placed across it with thin cross pieces, which can also be extended to any amount proportionate to the weight; so that there is no stone, of whatever weight, used in building, that could not be carried along any distance, without any other apparatus being necessary than an extension of the cross pieces; and if thus once raised, that could not in like manner be carried up an inclined plane and deposited as they are in the pyramids, &c. It is computed that on an average the apparatus weighs half as much as the stone itself.

† The temperature of my experiments.

No. 2.—"Chooreea, 1st sort." Belongs to the same class as No. 1; is more compact, and is of a faint pinkish tinge.

No. 3.—"Teeleea, 2nd sort." A coarser rock than No. 2, and finer than No. 1, belonging to the same class. It has a slightly crenulated appearance, probably due to the earthy and uncrystallized portions being washed out by percolation of water. There are distinct marks of stratification in this rock; its colour is deeper, and more earthy than that of No. 2, and it looks as if somewhat brittle.

No. 4.—"Dhoosur, 3rd sort." This rock belongs to the same class as the former rocks; it is, however, of much finer grain than either of them, and has a peculiarly soft and subdued buff tinge, which would look very well in a building. There is evidence, however, of minute patches saturated with iron being existent in it; and, if they be so to any extent, they constitute a disease which will diminish its value as a building stone.

Kyraghur series.—No. 1.—"Doodheea, 1st quality." A quartzose rock, very compact, and of agreeable colour.

No. 2.—"Doodheea, 2nd quality." This rock is of the same order, and similar to the preceding, but of coarser grain.

No. 3.—"Bullooah, 2nd sort." This rock is much of the same character in respect of structure as No. 4 of the Arail series: in it, too, there are symptoms of incipient disease through presence of iron. It has a slight yellow tinge also.

No. 4.—"Bullooah, 1st quality." This rock is well crystallized, and very compact on the whole. It is, however, pitted here and there by portions of uncrystallized earthy matter, which prevents it from taking on a smooth surface. It would probably be durable, and look well as a building material.

No. 5.—"Doodheea, 3rd quality." Closely resembling No. 1 of this series.

No. 6.—"Kukera." This rock is of corresponding character, though inferior to No. 2 of this series.

No. 7.—"Bullooah, 2nd quality." Corresponds in structure with No. 3. It wants, however, its yellowish tinge, and so far as my specimen informs me, it is free from the patches of peroxide of iron remarked in that rock. It has a bluish tinge, which is wanting in the other.

No. 8.—"Doodheea, 1st quality." This is the most compact and handsome rock of this series; but as, in the specimen, it was marked the same as another specimen far inferior to it was, viz. "Bullooah, 2nd sort," it must be left to the general report to assign to it its proper place. It approaches in appearance to No. 2 of this series, but is more compact, and with, at the same time, distinct marks of stratification.

Bara series.—No. 1. A compact semi-crystalline sandstone, of a dull reddish tinge, freckled with minute black spots. It is marked in my specimen "Doodheea, No. 3."

No. 2.—"Sufeid, 1st sort." Sandstone, with distinct laminar shades, the general effect being a rose colour. Why it should be called "sufeid," it is difficult to conjecture, unless on the supposition that there has been some mistake in the marking of the specimen. It would make a handsome building stone. It is somewhat less compact than No. 1.

No. 3.—"Goolabee, 2nd sort." Like No. 2, but less compact, and deeper in colour in the small specimen, indicating the presence of a greater proportion of iron. The larger specimen, however, differs from this, being almost white. I presume, therefore, from the name, that the smaller specimen represents the rock.

Atherbun series.—No. 1.—"Doodheea, 1st sort." A compact semi-crystalline sandstone, of an agreeable light colour, with laminar markings in the small, but none in the large specimen.

No. 2.—"Muttee Bullooah, 1st sort." Like the last in general structure; it is of coarser grain, and looks somewhat brittle.

Table of Weights, &c.

Number of specimen.	Weight of the specimen dry in grains.	Weight in water.	Mass of the specimen in grains of distilled water.	Weight when saturated with water.	Specific gravity.	Weight of an inch cubic in grains.	Absorbing power, the mass of the specimen being 1.
			ALLAHABAD ROCKS.				
			Arail Series.				
1.	530·5	302	228·5	550	2·32	584·93	·085
2.	646	369	277	659·5	2·33	587·58	·049
3.	743·5	441	293·5	743·5	2·50	630·51	·031
4.	525	309	216	536·5	2·63	612·36	·053
			Kyragurh Series.				
1.	866·5	500	366·5	891·5	2·36	595·67	·068
2.	693·5	399·5	294	716·5	2·36	594·9	·078
3.	877·5	503	369·5	897	2·37	598·83	·058
4.	837	489	348	846	2·40	605·99	·026
5.	787·5	454·5	333	812	2·36	595·82	·074
6.	716	419·5	296·5	732	2·41	608·41	·057
7.	659·5	381·5	278	625·5	2·37	597·71	·057
8.	875	506·5	368·5	899·5	2·37	598·24	·064
			Bara Series.				
1.	727	427·5	299·5	748·5	2·42	611·56	·072
2.	986·5	588	398·5	1010	2·48	623·71	·059
3.	902·5	539·5	363	924	2·49	626·41	·059
			Atherbun Series.				
1.	1060	628	432	1082·5	2·45	618·21	·052
2.	1066·6	623·5	443	1092·5	2·41	606·56	·059

*Banda Series.**—No. 1. "Mouzah Purdanwan." Sand-stone, compact, and slightly micacious; colour dullish red.

No. 2.—"Mouzah Maheepoor Burroha." Much the same as the last; colour more earthy, and not micacious.

No. 3.—"Mouzah Rowlee, 2nd sort." Structure like the preceding; colour more lively.

No. 4.—"Mouzah Buryaree, 2nd sort." A micacious sand-stone, of a purplish tinge in the large specimen, but whitish in the small one: the specimens are probably from different rocks.

No. 5.—"Mouzah Purdanwan." Resembling No. 2.

* With exception of Nos. 2, 3, 9 and 10, the small specimens of this series agree with the large ones in name only.

No. 6.—"Mouzah Mundyan Doodheea." A dull red micacious sandstone, stratified.

No. 7.—"Mouzah Buryaree Kulan." Closely resembling No. 1, but of deeper colour.

No. 8.—"Mouzah Girampoor." Limestone, unfit for building purposes, by reason of its incompactness, but more fitted by its purity to make excellent lime.

No. 9.—A red-coloured sandstone, tending to crystallization.

Besides the above specimens, one of clay iron stone was forwarded to me, which on analysis gives 82 per cent. of peroxide of iron. The product is not, however, likely to be of first-rate quality, as the usual proportion of manganese is wanting. The ore has a strong earthy smell, and looks slaggy, as if it had been exposed to great heat.

Table of Weights, &c.

Number of specimen.	Weight of the specimen dry in grains.	Weight in water.	Mass of the specimen in grains of distilled water.	Weight when saturated with water.	Specific gravity.	Weight of an inch cube in grains.	Absorbing power, the mass of the specimen being 1.
1.	682	404·5	277·5	704·5	2·46	619·21	·081
2.	1119	651·5	467·5	1159·5	2·39	603·06	·087
3.	923·5	530	393·5	964	2·35	591·29	·103
4.	827	479·5	347·5	857·5	2·38	599·59	·088
5.	1206·5	716	490·5	1238	2·46	619·72	·061
6.	1375·5	826	555·5	1409·5	2·48	623·86	·061
7.	1038·5	608	430·5	1073	2·41	607·79	·081
8.	987	591·5	395·5	1011·5	2·50	628·76	·024
9.	804	467·5	336·5	829	2·39	601·98	·031

Mirzapore Series.—No. 1.—"Mine of Rawurjara." A compact sandstone, lightly micacious.

No. 2.—"Mine Rodraj Putwarry." A sandstone of finer grain than No. 1, but reddened by presence of iron. These specimens show tendency to crystallization; No. 1, more distinctly than No. 2.

No. 3.—"Mine of Bhuwancepore." A bluish coloured sandstone, distinctly crystalline.

No. 4.—A granular sandstone of rather coarser grain, and somewhat brittle.

No. 5.—"Bhooripoori mine." A semi-crystalline sandstone; colour bluish grey.

No. 6.—"Potpurria mine." A sandstone of very fine grain and compact, with laminar markings; colour a rich buff.

No. 7.—"Dooreca koke mine." A compact quartzose rock, of a bluish colour, with minute black specks, of what appears to be hornblende. It is also slightly iron shot.

No. 8.—"Soanke Teree mine." Limestone of magnesian constitution, the proportions not determined. This limestone is exceedingly compact, though somewhat earthy, and coloured deep black by iron, with probably organic matter. It breaks with difficulty, and shows no difference of weight, when strongly dried in a sand bath, and after two days' immersion in water. It would doubtless be found a very durable stone for architectural purposes; but it is disqualified by its colour, on which latter account I have not thought it necessary to enter into a minute analysis of it.

No. 9.—"Rodraj Putwarry." A compact sandstone, of a light and lively red colour: of this, and the two following specimens, I had but small portions sent me, and they do not therefore appear in the table.

No. 10.—"Potpurria." A red rose-coloured sandstone, enriched by fine and distinct laminar markings.

No. 11.—"Tereea." A whitish and coarse crystalline sandstone.

Table of Weights, &c.

Number of specimen.	Weight of the specimen dry in grains.	Weight in water.	Mass of the specimen in grains of distilled water.	Weight when saturated with water.	Specific gravity.	Weight of an inch cube in grains.	Absorbing power, the mass of the specimen being 1.
1.	559·5	334	625·13	567·5	2·48	225·5	·014
2.	376·5	226	630·29	388	2·50	150·5	·031
3.	663·5	392·5	616·85	674·5	2·45	271	·016
4.	997·5	601·5	634·64	1012·5	2·52	396	·015
5.	652	389	624·60	660	2·48	263	·012
6.	690·5	417·5	637·27	701	2·53	273	·016
7.	882·5	536·5	642·63	889·5	2·55	346	·007
8.	1069·5	675·5	682·33	1069·5	2·71	394	·000

Agra and Bhurtpore Series.—No. 1.—"Bunsee Beharpore Bhurtpore." A semi-crystalline sandstone, of a light flesh colour, with indistinct markings of stratification.

No. 2.—"Roopbas Bhurtpore." A singularly beautiful granular sandstone, of fine grain, clouded cream colour, with minute sparkling points of mica.

No. 3.—"Agra Mouzah Joonaneh." A liver-coloured sandstone, somewhat relieved by minute yellow circular specks and fine laminar markings. The stone is nearly of as fine grain, but is less compact in structure than No. 2. This specimen is so perfectly identical in appearance with No. 5, that it is difficult to believe them other than products of the same quarry.

No. 4.—"Bhurtpore Roopbas." Similar to No. 3, but wanting in the yellow specks.

No. 5.—"Bhurtpore Bunsee Beharpore." *Vide* No. 3.

No. 6.—"Agra Tajpore." A granular sandstone of fine grain, handsomely striped with cream colour and light red, and dotted like No. 3.

No. 7.—"Bhurtpore Roopbas." A harsh, semi-crystalline sandstone; colours liver and soiled yellow, irregularly disposed.

Table of Weights, &c.

Number of specimen.	Weight of the specimen dry in grains.	Weight in water.	Mass of the specimen in grains of distilled water.	Weight when saturated with water.	Specific gravity.	Weight of an inch cube in grains.	Absorbing power, the mass of the specimen being 1.
1.	836	483·5	352·5	855	2·37	597·53	·023
2.	822·5	469	353·5	847·5	2·33	586·22	·030
3.	890	511	379	909·5	2·35	591·65	·027
4.	764·5	441·5	323	786·5	2·37	596·33	·021
5.	828·5	474·5	354	854	2·34	589·66	·031
6.	835·5	479·5	356	858	2·35	591·30	·028
7.	1128·5	646·5	482	1151·5	2·34	589·88	·020

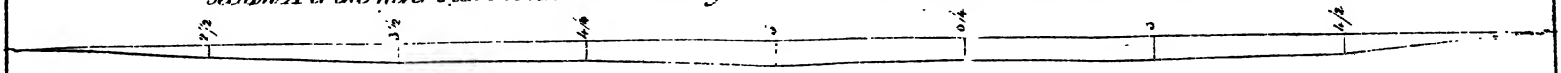
Quotab Minar.—It may be interesting, and also useful in respect of reference, to introduce here a description, corresponding with those given above, of the stone forming the crust of the Quotab Minar at Dehlie. This building, being probably about six centuries old, gives satisfactory evidence of the durability of the material of which it is composed. I have had no specimens of the Dehlie rocks sent me, and hence there is no report on them. The fragment which is here examined, and which I know to be genuine, belongs to my own private collection. There is no doubt, I think, but that the body of the pillar is made up of the strong quartz rock found abundantly in the neighbourhood, and which, from its compactness, and highly crystalline character, shielded as it is, moreover, from direct atmospheric influence, will remain undeteriorated, till the outer shell has been reduced to dust.

"Quotab Minar."—A sandstone of fine and equal grain, very much resembling in this respect the Roopbas stone. It is liver-coloured, with numerous, chiefly round, cream-coloured spots proceeding from the section of spheroidal masses of that colour.

Table of Weights, &c.

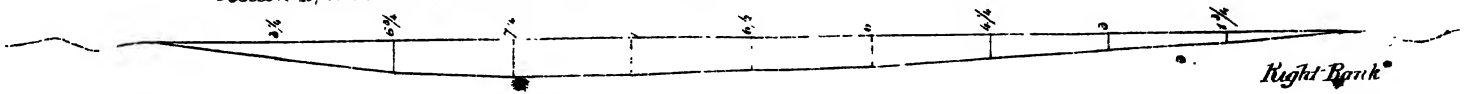
Weight dry in grains.	Weight in water.	Mass in grains of distilled water.	Weight when saturated with water.	Specific gravity.	Weight of an inch cube in grains.	Absorbing power.
1891	1076	815	1946	2·32	585·8	·067

Section A of the River Jumna taken at the Ty on the 16th March 1840 Breadth 320 feet



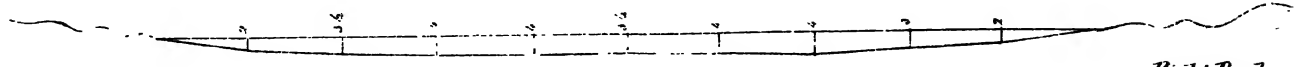
Right Bank

Section B, of the River Jumna taken one Mile below Bukrampoor 23d March 1840 Breadth, 250 feet



Right Bank

Section C, of the River Jumna taken at Middle of Sands just above the mouth of the Chumbul the 30th March 1840 Breadth 195 feet



Right Bank

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REPORT ON THE RIVER JUMNA, BETWEEN AGRA AND OOREAH.

SUBMITTED TO GOVERNMENT NORTH WESTERN PROVINCES. BY LIEUTENANT C. DOUGLAS, ARTILLERY. *Dated Agra, 6th May* 1840.

HAVING been appointed to the important duty of improving the navigation of the river *Jumna*, and a certain portion of its course having been pointed out to me as at present most needing attention, I proceeded, on the 16th March last, to make such observations on it, as would enable me to propose means towards effecting the object in view. The portion of the river pointed out to me, was that lying between the city of Agra and the river Chumbul, including, in its course, no great natural obstructions, but very many of a minor character. As the season was advanced, I satisfied myself with a cursory examination of the state of the river, noticing the sands, rocks, and other obstructions, the direction of the main channel when it branches, and the depth of water when less than four feet. In the annexed report on these subjects, I somewhat exceeded the limits assigned me, having proceeded as far as Bhudeyk.

2.—I shall now proceed to a general description of the appearance of the river when I visited it.

3.—The river, as far as I examined it, flows as a smooth navigable stream of little declivity, having neither rocks nor rapids, nor any other serious impediment, which would require the expensive aid of locks, &c.; and were a little of the care, bestowed in turning off the large portion of its water to fertilize the deserts of Bikaneer, employed in rendering the remaining portion of it navigable, its importance and value, as a commercial and military way through the country, would of course be much increased.

4.—Throughout this portion, it receives four nullahs; two, the Jhirna and Utungan, at present dry: the other two being the Chumbul and Sinde, affording a considerable reinforcement to its volume.

5.—Every appearance leads me to imagine that the bed of the river is in a nearly permanent state. I mean by this, that the high banks which bound the river during the rains are undergoing no material change. Between these banks, which are in some places a mile and a half apart, the small stream of the river, during the dry weather, varying in width from 50 to 250 yards, and in depth from 10 to 2½ feet, finds its tortuous way, at times divided into several channels, at times spread over a considerable space, and generally in both cases unable to retain sufficient depth for navigation. Its declivity is small. I had neither time nor instruments for ascertaining the amount of this; but from the velocity and body of water, I find it by calculation to be at the Taj, when I took *Section A.*,* 1 in 11,390, or 5·56 inches per mile. At a mile below Bickrampoor, where I took *Section B.*, I found the slope, by calculation, to be 1 in 18,407, or 3.44 inches per mile; and immediately above the junction with the Chumbul where *Section C.* was taken, I found the slope of surface 1 in 5,417 or 11·69 inches per mile. These calculations refer of course to the particular point in question, where the section was taken, and where the channel was straight; but the slope at the ends, &c. must be more considerable to overcome the resistance to motion at these parts. The surface velocity is generally about 1½ mile an hour.

* For these Sections, *vide* lithographed Sketch appended to this document.

6.—On comparing the above results, we observe that the declivity follows the usual law, being less as we descend; but there is a considerable anomaly in the slope just above the Chumbul, which is, however, entirely local, and accounts for the numerous sands and shallows there. This will again be reverted to.

7.—The banks are, on one side at least, invariably perpendicular clay cliffs; in some places 140 feet in height. The river during the rains rises so as to admit of no *gooning* path at the foot of the cliffs, which obliges boats to cross to the opposite side, sometimes occasioning a considerable delay, should the winds be unfavorable, and generally a loss of about half a mile in distance from the strength of the current.

8.—The channel during the rains is comparatively straight, it being thus enabled to deliver a greater body of water in equal time, because of its increased slope and consequent greater velocity. On the falling of the river, it makes for itself a new channel, which winds from side to side across the old one. It appears not to have continued always, as at present, there having been, to my knowledge, two great deviations, one at Buttaisur, where the river, I believe 150 years ago, turning off to the right of its present bed, flowed over the ground on which the fair is at present held, re-entering, its present bed at Noringy Baia. The other is below the confluence on the Sinde, the river formerly having left its present channel at a point near Beejwapoor, to re-enter it again at Bhudeyk.

9.—The dry weather current is much intersected by sand-banks, which render the main channel intricate: none are individually longer than half a mile, or of greater height above the water than two feet: so that during the rains they are completely covered, and the source of much annoyance. Instances of some formed by a sunken boat are given in the descriptive catalogue annexed.

10.—The character of the river varies throughout the portion of its course examined by me, and may be divided into three different portions.

11.—The first portion lying between Agra and Buttaisur, has a surface velocity at its head of 1·31 miles per hour: and a mean discharge of 1922·76 cubic feet per second, with a depth seldom exceeding six feet. A section of the bed of this portion, taken opposite the Taj, the breadth being 320 feet, is given at *Figure A.*, with the depth taken at intervals, and affording, by calculation, the discharge given above. This is the portion most obstructed by sands and shallows, and has no kunkur rocks or shoals.

12.—The next portion lying between Buttaisur and the Chumbul, has greater depth and a slower current than the first portion. It is also much more free from sands, shallows and other obstructions to the navigation, than the former portion, but has many difficulties peculiar to itself, arising from kunkur rocks and shoals. Its mean depth seldom exceeds seven feet; its surface velocity taken at its head is 1·203 miles an hour; and its discharge 1671·864 cubic feet per second. A section of the bed of this portion, taken when the breadth was 250 feet at a mile below Bikrampoor, and from which the above velocity and discharge were calculated, is given in *Figure B.*

13.—A section of the lower end of this portion was taken a quarter of a mile above its conjunction with the Chumbul, where the breadth of the river is 195 feet. It is represented in *Figure C.* It gives, by calculation, a surface velocity of 1·771 miles per hour, and a discharge of 1215·542 cubic feet per second.

14.—The third portion, lying between the Chumbul and the extreme point of my inspection near Bhudeyk, differs much from either of the preceding. It appears to be composed of a string of lakes, having a depth in some places of 25 feet, and joined together by shallower parts. The deeper parts had no perceptible currents. I found, from the short time I had at my disposal, and from the nature of the river, no

opportunity of making a section which I could depend upon in calculation. I attempted to get a section of the Chumbul, which would shew me the value of the addition of its waters; but having gone about seven miles up that river, and finding it a long continuous lake of half a mile in width, with a depth in some places of twenty-five feet and no current, I gave up the attempt. The wind was very strong in the direction of the current, but, even then, the surface velocity was barely half a mile an hour. The bed of the Jumna below the conjunction has quite the character of this part of the bed of the Chumbul.

15.—On comparing the above discharges, &c. at these three points, we observe that the distance from Agra to Bickrampoor is by the river 84 miles, and from Bickrampoor to the Chumbul 92 miles; both nearly equal. Secondly, that the loss by evaporation and other causes is in the former portion one-eighth, and in the latter one-fourth of the whole quantity, with which each commenced its course: the proportion in the latter part being doubled. Now, this loss, arising from evaporation, must depend upon the time of exposure of the water of the current, which must necessarily have in the latter portion only half the velocity of the upper. This satisfactorily accounts for the statement put forth in the 11th paragraph of this report, which gives a greater depth and a freer channel to the lower portion, although it contains on an average of its two extremes one-sixth less water.

16.—Many interesting subjects of inquiry were necessarily omitted by me, which would have been of great assistance: in particular, the slope of the surface of the stream, under different circumstances of width or curvature of the channel, which must be the foundation of all exact knowledge on the subject of rivers.

17.—I will now proceed to notice the objects I had in view in forming the descriptive catalogue.* It will serve as illustrative of my views, as I have generally, for each difficulty, proposed what I consider an appropriate remedy. It will show, by comparison, the permanency, or otherwise, of the dry weather bed of the river, and (as it may be expected at any rate, that if not always the same, there will at all times be a pretty equal amount of shoals and sands,) it may give an idea of the quantity of clearance that will generally be necessary. It can scarcely be considered an assistance to any one employed to remove obstructions, as he being necessarily on the spot, would not require to refer to it. I have framed my remarks on the sands, on the supposition that a channel of four feet in depth is sufficient for the largest boats frequenting the river in the dry weather, as it will admit of boats drawing 3½ feet without any difficulty. This depth, I am confident, can be secured in all parts of the river, by a proper application of the principles here following.

18.—In a running stream we must consider the area of section, the velocity of the current, and the fall or slope of the surface.

19.—There is in all rivers a certain mean velocity, which, if distributed over the whole course of the river, would cause the water to be delivered in the same time as in nature. This is the perfection of a river, and our endeavours should be to imitate it.

20.—The earthy matters in suspension vary, increasing in proportion to the increase of the velocity of the current, and *vice versâ*, and the effect of an equable

* The catalogue here referred to contains a detailed description of all the obstructions and difficult passages between Agra and Bhudeyk, and is accompanied with a running sketch of the survey made to Government by Lieutenant Douglas; but it has not been deemed of sufficiently general importance for insertion in the *Selections*.

velocity is to prevent the deposit of these matters, where the current is slow, and to take up fresh matters when the current increases. It appears that, in nature, a species of equilibrium always exists between the velocity of the current, and the resistance of the bed; hence no deposit can take place in a state of undisturbed nature; but when to serve any purpose of our own, in improving or altering the channel of the river, we unsettle this state of permanency, we may cause deposits to take place, and produce more inconvenience than originally existed, unless guided by the principles of nature.

21.—In fact, success can never be expected in any operations relative to the course of rivers, if we do not act strictly in accordance with these general rules of nature. Should we, for instance, deepen or widen any part of a river, without making any other corresponding change, we would soon find our alteration choked up with a deposition of sand, because we had enlarged the section, without increasing the supply.

22.—The faults which it may be desirable to correct in rivers may concern the velocity or the section of the stream, or we may wish to remove or avoid existing impediments, as rocks and sands.

23.—The current may be too strong. This arises from a greater slope in the stream than usual, and may be corrected by increasing the length of the channel, making a straight channel winding, or a winding one more so, till we have reduced the slope of the surface to the proper and usual amount. In doing this, we can always take advantage of the off-sets from the principal stream; and choosing one of those best suited, make it the principal channel. We should, in choosing a new channel, examine its bed, to see if there are any natural impediments to its acquiring a sufficient depth, such as rocks, or kunkur reefs, across its channel.

24.—But an increase in the strength of the current often arises from the nature of the stream above. Should the stream, for some distance above, be spread over a large space, it has but little depth. The increased friction retards the current, causing deposits, which raise the bed of the wide part, giving it consequently less slope. This increases the slope, and consequently the velocity of the lower portion; whereas, were the whole fall distributed equally through both portions, the velocity of the upper part would be increased, while that of the lower would be diminished, and both would be improved. Now, to improve such a channel, all that would be required would be to contract the width of the upper channel, by bandels, &c. The immediate effect of this would be to obstruct the passage of the water; but as the whole of the river must pass, the surface above the artificial contraction must be raised, till the head of water affords sufficient pressure to increase the velocity to the necessary amount. This increased velocity must deepen the channel at the contraction, till its section be as great as before, and will remove all that portion of the bed, which, though adopted to its originally slow channel, interferes with the slope now required for its greater velocity. The slope at the upper part will thus be increased, and the fall of the lower decreased, as was desired.

25.—Sometimes, from natural causes, the channel is narrowed, and a rush of water ensues from the decreased section. This increased velocity will continue under any circumstances of the river, above or below it, and the only means of getting rid of it, is by widening or deepening the channel. If merely a gorge, as at Noringy Baia, or if a continuation of rocks, &c., for any considerable distance, and if the channel cannot be rendered deeper, it should have its slope diminished by being conducted in as winding a direction as possible among them.

26.—The current may be too slow; this is no impediment, but, on the contrary, an advantage, did it not generally happen when the section continuing the same, the river is spread very considerably. This may be cured by simply contracting the breadth by bandels, &c., without making any other alteration in the direction or length of the channel, except, if requisite, making it take a more direct path, which would of course give it increased velocity, if sufficient could not be obtained by contraction, to enable it to make and retain sufficient depth. A slow current may also arise in consequence of an increased area of section, as in the case of the Chumbul, for the last eight or ten miles above its conjunction with the Jumna, and in the case of the Jumna below this point. (See paragraph 14.)

27.—When the section continues the same, but the velocity increases, the slope of the channel must be greater than usual. In this case, when there is a scarcity of water, and the depth is inconveniently diminished, we may correct this, by increasing the windings of the river, or may take advantage of the most winding branch of the river, conducting the body of the stream into it.

28.—I will now give a description of the different sorts of impediments to the navigation, such as sands, shallows, rocks, old buildings, sunk boats, trees, abrupt turns, &c., with the treatment for each particular sort.

29.—Sands may be prevented from forming, by attending to the rules already mentioned. Where so numerous as to impede the navigation, a channel should be selected from among the number into which the river is divided, with a reference to the previous rules, and by it should the whole stream be conducted, or as much of it as is required. The most important sand in the part inspected by me, is just above the junction of the Chumbul and Jumna, and I can only thus account for it. The section of this place, (see paragraph 13) gives a considerably greater slope of channel than that usual in the river, which can only happen by the Chumbul being on a lower level than the Jumna; and should it be found that the freshes of the Chumbul arrive at the point of junction, sooner than the corresponding one of the Jumna, which from its shorter course may probably be the case, it will act as a dam to the Jumna obstructing its waters, causing them to let fall a considerable amount of the sand held in suspension. That this may easily occur, a little reflection will show, as the slope of the Jumna being 11·69 inches per mile, the Chumbul has only to rise that amount, to render stagnant a mile of the Jumna above it, which would include all these sands. The only motion the Jumna could have, would then arise from the *vis à-tergo* of the stream above. Should the fall of the Chumbul, like its rise, also precede that of the Jumna, the usual difference of level between them would be increased, and it would account for the great rapidity of the Jumna above its junction, at the close of the rains, and in fact till it has resumed its dry-weather bed. It is worthy of notice, and is in favor of the above idea, that this great velocity at the close of the rains is only above, and does not extend below the junction, the water being there comparatively slow. There are some sands for about a quarter of a mile below the junction, but they arise from the washed-down particles of the sands above the junction, here deposited in consequence of the loss of velocity in the Jumna, by its meeting so slow a stream as the Chumbul, and at an angle of about 120°, which must destroy a considerable amount of motion. The Chumbul brings no sand into the Jumna, the large and deep lake, forming the last ten miles of its channel, acting as a filter to its waters, allowing its sands to be deposited in its own bed.

30.—The general methods of improving such parts of the river are already pointed out, and consist, in this instance, of decreasing the slope of the current, by

causing it to wind as much as possible among the sands, and closing the direct channels, which being the readiest exit for the water, would prevent the formation of a good winding channel. In general, and in this instance, the requisite operations are already planned, and partly executed by nature; as may be seen by a reference to the figure; and all that is required, is to modify her plans, to suit our particular wants in depth, &c.

31.—The motion of sands may be ascertained by observing the motion of ripples. These are formed transverse to the current, and are moved forward by the current rolling the particles up the exposed side of the ripples, whence they fall over on the *lee* side. The ripples, by these abstractions from the upper, and additions to the lower side, move forward in the direction of the current, and do not rest till they arrive at the *lee* of the sand-bank where the current has no effect on them. This operation takes place at the surface of all sands, at the rate of about two feet per hour, sand being thus abstracted from the upper to be added to the lower end. The following is an attempt to deduce from the motion of the surface ripples, the amount of motion in the sands to which they belong. Should the ripple be considered half an inch in base, and one-fourth in height, the sectional area of each ripple will be ·125 square inches, and as there are 24 of these contained in the distance of a foot, the area of section of these contained in a foot will amount to 1·5 square inches, which requires half an hour to progress one foot in advance of its last position. If we suppose the average height of the sand above the general bed of the river to be four feet, the area of the vertical section of the ripple sand, (by which such a sand will require to be increased to enable it to advance one foot,) is 2,304 square inches, which, divided by the area protruded that distance per hour by the advance of the ripples, or three square inches, will give the time 768 hours, or 32 days, about one month, required to enable such a sand-bank to advance one foot in the direction of the stream. This I think must gradually alter their position, driving them lower down the river at the above rate. The descriptive catalogue will afford data for any future comparison to elucidate this subject.

32.—The worst description of impediment is that arising from kunkur rocks, where they occur, which is very rarely, and more generally as spurs from the bank; they are noticed in the catalogue. They usually occur on the concave side of the river, where it is more difficult to avoid them, or to alter the direction of the current. In this case, they should be blown up; at any rate, their situation should be indicated, a mode for doing which will be pointed out subsequently.

33.—Kunkur reefs, or beds of kunkur gravel, are, in the portion of the river between Buttaisur and the Chumbul, of very frequent occurrence. They sometimes occupy the whole of the main channel, with a small depth of water over them, which no effort of the river can increase. Their importance depends much on the position they hold, as to whether, when in a bend, they are on the concave or convex bank. When in the former, the loaded boats of the descending trade find it difficult to avoid them. In the other case, there is no difficulty. Should there be a choice of channels, it will be as well to examine one of them, and should it prove free of this sort of obstruction, make it the principal one.

34.—A few old buildings and their fragments, old wells, &c., occur in all situations in the river; they are all noticed in the catalogue, and should, when possible, be removed by blasting; but if this be not expedient, their position, if liable to be covered during the rains, should be pointed out by beacons, in the manner explained hereafter.

35.—Sinuosities may be considered advantageous by their diffusing more widely the advantages of rivers. But the contrary must be thought of; thus at Buttaisur, where the sweep of the river causes great delay to boats with no counterbalancing advantages, it has been considered an object to restore the ancient channel, which would allow of accomplishing in one hour what now requires six. The river once in every three or four years runs, in the height of the rains, in small quantities along its old bed. But it would require very careful levelling, to enable me to give an opinion of the practicability of causing it to re-occupy its old bed. The river itself would be employed in cutting its new channel after a method which is hereafter pointed out. The current is exceedingly slow at the bend in question, which may give us hopes that the more direct channel would not have too much slope.

36.—A sinuosity, when in the shape of an abrupt turn, is a considerable inconvenience; for by it the force of the current is thrown on the concave bank, conveying with it the boats of the descending trade, and rendering it difficult for them to avoid serious collisions with the banks.

37.—Sunk-boats, trees, &c., are the most dangerous of impediment. There are at present many of the former in the river, as pointed out in the catalogue, but none of the latter. This may be accounted for by the consideration that trees being valuable property, and belonging to whoever chooses to secure them, are speedily taken out of the river, whereas a sunk-boat is the property of an individual, who knowing he cannot be dispossessed of it, is in no hurry to remove it. Such boats as are whole, are, on the rising of the river, taken out by the owners; those which are seriously injured, are left in their places, being scarce worth the trouble of removing, from the difficulty of clearing the sands away from them. If they remain in one place, they become known and less dangerous; but should they become loosened, and drift down the river, they may occasion much mischief, as they slide along the bottom of the bed of the river, and cannot always be noticed.

38.—I now come to the methods I propose to be used, for improving the navigation. They resolve themselves into closing up old channels and forming new ones, contracting the breadth, deepening the bed, and directing the bed by various constructions.

39.—None of the works undertaken for these purposes can be permanent, as in the rains they would cause more inconvenience than the faults they would be intended to correct, and would run the risk of being swept away. Besides, as most of the operations refer to sands, which cannot be expected to remain in successive years in the same place, the works of one year could not be expected to be useful the next, and would in all probability create harm. Such operations must be repeated annually; but the expense need not be much after the first year, as the materials may be used in succeeding years, being during the rains stored up near the spots on which they are required. The works in one place may effect their object in a few days, when the materials composing them may be removed and applied at some other station lower down the river, to which they may be floated. They may thus be usefully employed, performing the journey from Agra to the lowest point of the river requiring improvement; by which time, use may have rendered them unfit for the purposes required of them, and they may be discarded; a fresh supply being always in receipt at the highest point of the river under improvement, where, besides, their expense of purchase will be less.

40.—Should it be advisable to change the channel of the river, it may be done by throwing the body of the stream into some minor branch, and obstructing the old channel. The old channel may be obstructed by bandels, or by an earthen bund,

The bandels may consist of stakes forced into the sand, wattled by brushwood, which may be cut from the banks; or by long grass, sugarcane leaves, or such other materials. When wattled with brushwood, the twigs should point up the stream, as by this they are enabled to catch and retain straw, &c., floating down, which will assist in rendering them more impervious. The length of the stakes, if placed perpendicularly, need not exceed the depth of the water, by more than the length required to give them a firm hold of the sand; but if placed at the slope, the sands naturally assume, (which is their best position, and will favor the deposition of sand on them, and prevent the current guttering their foundations, rendering them less pervious,) a greater length will be necessary. The current may be obstructed by a mound. This can only be required when the new channel is exceedingly small, or when it requires to be formed artificially. The bund should be constructed, as shewn in the next paragraph, of the most tenacious earth procurable.

41.—A *nucleus* of some sort will be required to construct the bund: this may consist of a double row of bandels, placed standing, so as that they may be considerably apart below, and nearly meeting above; or it may consist of a small row of gabions, made in the usual way, placed close together, and nearly filled with earth, &c., the interval between each pair being filled up with fascines; and earth being thrown on their upper side.

42.—Protection of the nature of an embankment is sometimes required to protect buildings from the force of the stream, which tends to undermine them,—an evil which very little can be done to palliate. A line or lines of strong bandels, gabions, &c., may be placed, or stones or bricks, when available, may be thrown in, and allowed to find their own slope. This latter is the best description of palliatives. But the correct mode of treatment, when we are at liberty to avail ourselves of it, is to direct the river above, so as to cause it to fall on some point of the bank above the building to be protected, and at such an angle, that the stream may be reflected clear of it. Here the evil is transferred to other points of the bank, where erasions are of less consequence.

43.—When it may be necessary to cut a new channel, (as would be the case, did we wish to cause the river at Buttaisur to resume its former more direct course, or the stream at the city of Agra to run along the city strand,) the labor and expense of forming the channel may be considerably lessened by digging, in the line of the new bed, a series of ditches running parallel to each other, in the direction of the new bed, through which the water may flow; and the increased velocity given it by obstructions placed in its old channel, will cut up and carry away the intervening ridges of earth or sand,—an effect which quickly takes place in times of flood.

44.—The breadth of a river may, when necessary, be contracted by forming piers, or dykes of bandels, &c. The object of the construction is to prevent or remove bodies of sand, which it effects by increasing the velocity. The upper portions of the stream being retarded, the level rises until the slope become sufficient for the discharge. With the increased velocity the stream will have sufficient force to carry away the earthy matter it before deposited, and a permanent improvement in its depth will be made.

45.—As a stream tends to continue of uniform section even in an increased channel, it is not necessary that this contraction should be effected by continuous and parallel lines of dykes or bandels. It is sufficient that piers or spurs be built out alternately from each bank, or in opposite pairs, the distance between each line being equal to the breadth it is proposed to give the stream. The heads of these piers

should be arranged if possible in two parallel straight lines, in order that the stream may assume a straight course, in which it will of course have the maximum velocity. The deposits, which were formerly distributed uniformly along the bed, will now be taken up, and left in the dead waters between the piers, rendering the centre of the channel deeper.

46.—There is still a means of deepening the beds of rivers, but which is only applicable to tidal rivers. I mean dredging. I have seen a newspaper notice of the expense of dredging the river Clyde at Glasgow, which mentioned that it was three half-pennies per ton; but when we can cause the river to remove its own impediments, it will not be necessary to have recourse to manœuvres of force, which besides, where machinery is concerned, must be very expensive in India.

47.—Hand dredging may, if required, be had recourse to as follows. Let a series of *fouras* be attached to a long rope, by lashing their handles to it. This chain of *fouras* may be suspended, at a distance below the surface equal to the depth we may require to give the channel, by buoys attached at intervals along the chain of *fouras*, by means of small ropes of the necessary length. This when drawn down the stream by some contrivance, employing the strength of the current, as the motive force, will stir up the sand, and assist a contracted channel in carrying it off, thus shortening the time that would otherwise be required to deepen the channel.

48.—It is often requisite to give a new direction to the current, as in the instance of the strand previously referred to. This may be effected by piers or spurs made of bandels, or by rows of gabions lined with mats, filled with earth or sand; each succeeding row, as we leave the bank, consisting of one fewer than the last. They will require to be laid somewhat slanting, so as to approach the natural slope of the bank, and may form any angle with the bank, according to the object in view; that of *maximum* effect, being an angle of 45°. They are apt, however well constructed, to form eddies and whirlpools, and this effect should be as much as possible avoided by making them form with the stream as small an angle as possible, making up for the decreased effect by removing the pier further up the river; but in this case its projection into the stream must be proportionably increased.

49.—I have in some places referred to beacons to be used for indicating the position of rocks or other dangers. They should I think be constructed of masonry, and always in pairs, the pair being parallel to the direction of the current, and on a part of the river's bank nearest the impediment, but above the reach of the highest floods. They will be placed directly opposite the impediment, and by there being two, they can be placed at a distance apart equal to their common distance from the danger which will afford a simple and perfect means of ascertaining its position.

50.—Buoys will form a very efficient sort of beacon, but should never be employed if other means are applicable, as the materials they must be made of are too great a temptation to theft, to permit of their being long lived.

51.—Should a steamer be sent up the river, the channel might be laid down by buoys, placed at impediments; those on the right side being known from those on the left, by being painted of a different color.

52. —A *gooning* path is very necessary in many places, as during the rains, the river runs at the very foot of the high clay cliffs, forming its banks, leaving no room for gooning. Boats are hence necessitated to cross the river, which is not always practicable, and when so, it entails a loss at times of half a mile from the strength of the current.

53.—I have already, in paragraphs 5, 8 and 39, given reason for the opinion that the works will necessarily be of a temporary description, requiring renewal each year

at the close of the rains, when the river has so far fallen as to allow of a definite idea being formed of what channel it intends occupying during the dry weather. The necessary works, which will then be commenced, need not I think occupy more than a month, during which time, the river, though falling, will not do so to such a degree as to impede the navigation, before the good effects of the works are produced. The person superintending will proceed down the river in a fast boat, taking with him a supply of men and materials, sufficient to last till an opportunity again occurs of replacing them. A portion of these will be left where desired, with directions what to do. The superintendent will in this manner proceed down the river, and when the whole line has been supplied, will return in the most expeditious manner to Agra, again to proceed down the river by boat, to examine and correct the works which, it is expected, will by that time have nearly effected their intended objects. The men may be then discharged, except a small establishment and native writer (Lalla,) left at intervals on the river to make reports, and keep the works in order. When the operations are all completed, and a good channel secured, the materials may, generally speaking, be removed, and laid up in store, in the neighbourhood of the spots whence taken, ready for the operations of succeeding years. The river will afford means for the carriage of materials, and as they decay or are lost, others to replace them may be floated down the river from higher stations, where probably they are cheaper. It is probable, that in each season a small quantity of materials may be made subservient to the operations required, over a considerable space of river, as the time required to effect the object in one place, may admit of their being removed, and repeatedly re-applied elsewhere, lower down. But this experiment should not be tried the first year: lest the saving of expense be counter-balanced by a more than equivalent sacrifice of time.

54.—The last consideration is whether the necessary expense be warranted by the advantages, supposing them gained. The advantages may be estimated by the value of the merchandise on the river during the eight dry months, when only the boats have any difficulty: and by the saving of time consequent on the operations. I have instituted an inquiry regarding the trade of Agra, which I shall shortly be able to submit; but in the meantime will take a hypothetical case, viz., that the total merchandise received by Agra, from below, and sent from Agra down the river, amounts during the above eight months to one lac of rupees, and also that the present detention, on an average of the descending or ascending trade, amounts to one-fourth of the whole passage; that is, that goods conveyed in eight months might, by the improvements, be conveyed in six months. The advantages will therefore consist, first, in the interest of one lac of rupees for two months at 10 per cent. 1,666 rupees; second, the hire of the boats necessary for transporting this amount of goods, which, if cotton, at ten rupees per maund, or 10,000 maunds, will require for carriage, ten boats of 1,000 maunds each. The hire of these ten boats for two months each, at 2 rupees per 100 maunds, will amount to 400 rupees; and third, the wages of the crews at eight men per 1,000 maunds, and three rupees each per month, will, for two months, amount to 480 rupees. Thus, we see, the saving effected by the improvements will, on one lac of rupees worth of cotton, amount to $1,666 + 400 + 480 = 2,546$ rupees; equal to, for the whole dry season, $2\frac{1}{2}$ per cent. on the whole merchandise received and dispatched. This would admit of an equal tax being levied for the expense of improvement, and the balance of advantage would still be in favor of the merchants, both from the time saved and from the smaller crew required for boats in the improved state of the river. The above is merely a formula of the method I would employ for making the comparison of advantages and expense, and to this it will be easy to apply the proper numbers.

Letter regarding the above Report. From MAJOR E. SMITH, *Superintending Engineer, Central Provinces, Allahabad, the 11th July 1840, to* CAPTAIN H. DEBUDE, *Officiating Secretary Military Board, Fort William, No. 405.*

SIR,

I have the honor to submit the result of my examination of a report by Lieutenant Douglas on improvements contemplated in the river Jumna.

2.—This memoir is long, but a brief analysis will permit of my distinguishing the parts which are of most interest, or which particularly require the notice of the Board. Many pages of the report are occupied by statements of the usually received theories and rules on the nature and treatment of rivers; but which expositions are not of consequence, except in indicating an acquaintance with the subject by Lieutenant Douglas, sufficient for the regulation of such practical operations as may be committed to him. Paragraphs 15 to 27, 29 to 31, 35 and 36, are given chiefly, if not entirely, to the theoretical matter mentioned, and therefore have no direct reference to the present questions. Another considerable portion of the paper contains a general description of the river between Agra and Buddek, or Kurrim Khan, with the introduction or application of some theory to the observed appearances. The general nature and more evident characteristics of this part of the river are correctly stated, though with the occasional defect of a mistake of annual and changeable, for permanent, conditions of the stream and bed; and in consequence, with some erroneous conclusions on the supposed circumstances. Paragraphs 3 to 14, 28, 32 to 34, 37, 38 and 54, are mostly of the nature explained,—of description accompanied by theory: and other portions are of miscellaneous matter of the same tendency, but which have little close concern with the practical objects of the report. The part chiefly of utility is found in paragraphs 39 to 53, in which Lieutenant Douglas sets forth measures he recommends for the improvement of the river; and here, having dropped much of the previous theory, his suggestions become of a feasible and simple character, being in short, propositions for enlarging the body of water in, and consequently deepening, certain sandy and obstructed channels; the mode of operation being the ordinary one of throwing up spurs and dams. In regard to this work the Executive Officer's views are sufficiently true, except in the sanguine announcement which he makes of the facility of removing obstructions, and his confidence in the adequacy of small means for accomplishing work of such extent. In his list no fewer than 88 spots are mentioned, at nearly the whole of which some labor is projected, and in most of the cases constructions of considerable size, while the means calculated are on an inconsiderable scale, and the time for accomplishment is equally limited.

3.—This power of quick and easy execution cannot be surely depended on; for there is little experience of such work to give a pledge of success, and the attempts proposed must, too, be somewhat uncertain in their results, from the temporary nature of the works, and from their being based on mere sand. But though these considerations should dictate caution and temper, promises of great consequences, it by no means follows that the intended efforts are to be relinquished. The plain measures indicated are those offering the best prospect for an amendment of the channels, and they certainly should be tried, but at first only on a moderate and experimental scale.

4.—Instead therefore of undertaking numerous works, of every grade of urgency, attempts should at the outset be limited to three or four of the most obstructed passages; and on the results attending these first essays, improvements may be undertaken upon safer grounds than now exist, or are to be perceived. I do not find it expedient to specify the places at which the experiments should be made, but three

or four of the worst between Agra and the Chumbul or Buddek, may at the close of the rains be selected, and proceedings at these spots be entered upon. The exact situations are not named, because it is not certain that obstructions will present themselves next year at the spots where they now exist, but the confluence of the Chumbul, it may be concluded, will be enumerated among the difficult passes, as that part of the bed is almost annually one causing detention.

5.—To bring the projected work and expense within more defined limits than it now appears in the Executive Officer may at once frame an estimate for a full trial of improvement at four places, and, after an examination of that preparatory document, he may be authorized to proceed with these first labors as soon as the state of the river admits and calls for progress. He should not undertake work on any particular part which this season has been obstructed, under the idea that it will next season also be shoal, for that would be to anticipate a state of the stream that might prove of no real occurrence, but should fix on spots at which difficulty of passage is actually encountered; and, if the measures adopted prove efficacious in a remedy of the condition of those places, there then may be placed trust in assurances of the general utility of such management of the river.

6.—Some of the obstruction mentioned by the Executive Officer are kunkur shoals; and these he speaks of removing; but that work, if sanctioned, should not be entered upon, except upon closer evidence of its necessity, as also on proof of the power of effecting it thoroughly. Some of these kunkur beds are troublesome, but they have not hitherto been found to be the most serious obstacles in the navigation of this part of the river; and they should not be meddled with, except with caution. A partial removal only aggravates the evil, and a complete clearance is of serious labor, and ought not to be commenced except upon the production of plans on scale, shewing the entire dimensions of the obstruction and the amount of the work to be undertaken. Kunkur shoals, too, should not be removed without a knowledge of their usual effects extending over more than one year; for a mass which is of inconvenience in one season, is not unfrequently of more than proportionate benefit in another, by defining channels which otherwise would become expanded and shoal.

7.—Upon other points, the Executive Officer speaks in terms of certainty which longer experience might have shown him the necessity of measuring. His proposed masonry marks or beacons, on the edge of the river, for instance, are of the nature of some of those which were erected under my directions eight years since; and certainly when properly understood by the boatmen, may become of great service; but it is not so easy to determine the arrangement of the pillars in such a manner as to be at once comprehended by the native crews. Floating buoys, again, of a nature to be depended on, are not to be fixed so generally as he supposes, unless great expense is to be incurred. Numerous trials have shown that there is but one kind of buoy or mark which will meet the various objections found to attach to the greater number of those patterns which at various times have been proposed and tried, but a determination upon even the most promising description can only be made with some reservation, and its application should be carefully studied.

8.—In the removal of portions of masonry, too, which may be somewhat dangerous in themselves, guarded forbearance should be used, as in this case also the disappearance of an obstacle might be attended with the production of a larger extent of obstruction; and at least, many of such spots should be worked on only after the expediency of the projected clearance has been shown on distinct plans, or proved by mature examination of the locality.

9.—There will unquestionably be advantage in cutting towing paths on those parts of the bank in which the communication is interrupted by bluffs or other impediments, and the Executive Officer can include such work in the estimate which he is to furnish. Carefully made paths are not requisite, but merely such tracts as the boatmen are in the habit of traversing. The removal of wrecks and submerged trees will also be a continuation of the original operations on the river, which cannot but be approved; and for such work Lieutenant Douglas may estimate, recollecting that such clearances should be complete, and that the remnants of these sunken bodies, if any be left, are productive of greater danger than the entire and more conspicuous mass.

10.—In going through the Executive Officer's report, it will be perceived that I have for the time confined myself to recommendations and suggestions for that part of the projected work which is of the most consequence, viz. the schemes for deepening the channels which are obstructed by shoals. The immediate measures which I conceive desirable for the furtherance of this project are mentioned, and the propositions for the other branches of the contemplated work can be better entertained in detail when I am in possession of the Board's sentiments on these general observations on Lieutenant Douglas's report.

11.—By that officer's accompanying letter, I am promised an account of the result of the attempt, on which, under the authority specified, he has been engaged for bringing a branch of the Jumna back to the edge of the strand at Agra; and the purport of his communication, when known, shall be submitted to the Board.

12.—Lieutenant Douglas's report, herewith transmitted, evinces intelligence and active research on the part of that officer, although as pointed out, its utility would have been greater had its contents been modified by that experience and abstinence from wide speculation which appear to me to be wanting in it. His sketches also, though of service as illustrations, cannot be relied on as indications of facts, as they do not seem to be drawings on scale, whereas, as I have mentioned, real dimensions are necessary to a judgment, on the more difficult operations in altering the channels of rivers.

MEMORANDUM UPON THE IMPROVEMENT OF THE NAVIGATION OF THE GANGES BETWEEN ALLAHABAD AND REVELGUNGE,

By Mr. E. A. Reade, *Commissioner of the Benares Division.*

In this paper, I propose confining my remarks to the practicability of removing obstructions to the free navigation of the river, throughout the extent of country above indicated.

Removal of obstructions between Allahabad and Revelgunge.

2.—It will be convenient to treat of it in three portions; Firstly, from Allahabad passing Sirsa and the river Tonse to Bouroobpoor, the extreme west of the Mirzapoor district; and the Benares Division.

To be treated of in three divisions of the whole extent.

Secondly, from Bouroobpoor to the conflux of the river Goomtee with the Ganges.

Thirdly, from the Goomtee to the junction of the great Surjoo, or Mahadeva, or Gogra; which last name had better be adhered to, to avoid confusion of it with the intermediate Surjoo.

3.—Of the first portion, having learnt little or nothing, and hoping to receive shortly some precise information, I will treat last; but, before considering the second portion, I would offer a few remarks on the subject of gaining good information.

First in order, still under enquiry. Difficulties of obtaining correct information.

4.—Facts respecting navigation must be learnt afloat rather than ashore; a residence of five miles from the river side is a disadvantage. Little or nothing can be learnt on the subject from the records of the recent professional survey. The surveyors' district maps, that of Rennell; and a map of the River Ganges, from Calcutta to Allahabad, from surveys by Major Colebrooke, corrected by Captain Thomas Prinsep in 1828, are the only records I possess. The caprices of the river Ganges, so to speak, render it impossible to rely permanently upon information on record, however accurate it may have been at the time. To obtain present correct information is a far more difficult matter than might at first be supposed. The truth of this remark will soon be apparent to any one who will endeavour to collect facts from the crews of different native boats, regarding shoals and similar obstructions. Their diversity of evidence is beyond measure perplexing. Whether it is, that, their acquiescence in the yearly mutations, or even still more frequent changes, in the main course of the river, is so completely passive, that they dismiss from recollection any obstacles which may have impeded their progress, but which have been surmounted without peril to their craft; or whether they have, for some inexplicable reason, a dislike to communicate their experience, little trustworthy information is to be gained from them. They are notably apt, it is known, in remembering localities with remarkable precision, even after the lapse of years. They all know, well enough, the exact position of peculiar dangers, such as a rock, a sunken tree or a kunkur bed; but beyond this they are not careful to trouble their memories. Their vessel runs aground on a shoal; the difficulty is surmounted with or without assistance, and is forgotten. I cannot fix, within ten miles, the spot where one of the Company's steamers was totally lost some years ago.

Reasons of these difficulties. Mode of enquiry necessary to elicit truth. Imperfect records. Perplexing contradictions of native navigator's testimony. Why it should be so, with native aptitude for remembering localities.

5.—The native pilots doubtless are better informed. Shoals and sands are matter of more interest to them in their vocation, than to the ordinary navigators; but they have yearly to gain fresh information regarding their respective beats; the experience of the preceding year is of little avail; and I apprehend that their experimental discovery of obstructions, is more frequently derived from vessels in their charge coming in contact with them, than from any previous knowledge derived from a careful survey, and continual soundings.

Pilots: the extent and accuracy of their information.

6.—It is then primarily necessary, as part of a scheme to remove obstructions to the free navigation of the Ganges, to insure a continual and prompt transmission of the experiences of competent persons. For this we must look to the commanders of the various steamers which ply on the Ganges. Extracts from their logs will doubtless be cheerfully contributed. Obstructions will thus be discovered, denoted and appreciated. These communications may be digested into a valuable and useful record, and the next step will be to turn it to good account.

Value of the records and certified statements of commanders of steamers.

7.—For this purpose there must be a special agency directly employed, the efficiency of which will be much augmented by the supervision, countenance and encouragement of Government officers, who are placed in positions which will enable them to render support to an important undertaking.

Special agency required to prosecute enquiries, and digest evidence with the countenance and aid of Government officers.

8.—I proceed to consider the obstructions, which exist between the western extreme of the Mirzapoor district and the Goomtee.

Nature of the obstructions btween Mirzapoor west and the Goomtee.

9.—Herein, as far as my enquiries have assisted me, it appears that the locality of certain rocks and kunkur beds are perfectly well known to native boatmen, and Captains of steamers:* they can be avoided; and although their removal or reduction would be a great advantage, yet peculiar professional skill must be called in to estimate the cost of effecting the whole or portional reduction; and they must necessarily be reserved for future consideration. A correct record of these permanent obstructions within the Benares Division, will be attempted after the recess of the Ganges, to be hereafter submitted to Government, and if necessary to be inserted in the public prints, to invite attention and discussion respecting the most practicable method of effacing them. It will rest then with the Government to determine, whether it will be advisable to apply an agency, similar to that which was used in blasting and dispersing the rocks in the river Jumna, with the aids of recent scientific improvements. I only pretend to deal with obstructions of inferior character.

Rocks and kunkur beds; a complete and accurate record in course of compilation. Their treatment requiring peculiar professional skill to be applied, it will be better to reserve them for subsequent consideration.

10.—The obstructions, in this portion of the Ganges, are sand-banks cast up diagonally of the main course of the River. The most common, are, what may be called, hard banks in contradistinction to shifting sands: because the former have some pretensions to permanency: the latter have none. Of these, the most notable is a shoal below Sultanpoor, and another not far from Mirzapoor Cantonment. These, last year, proved

Hard sand banks, diagonally, of the main channel, the ordinary obstructions. Successful experiment of removal by Major Hill. His apparatus described and improvements suggested.

* Perhaps I ought to make a reserve regarding the rocks near Deocheepoor, inspected by Executive Officers of the Division, by orders of Government.

a serious impediment to navigation; and, in one, the difficulty was overcome by a very simple process. Major Hill, commanding the 4th Irregulars at Sultanpoor, (of whose experiment the public are aware,) effected a passage through the obnoxious shoal, by a process similar to what (if my memory serves me,) is called "jobbing" in the Thames. He formed a fleet of boats in the shape of a cone, the apex down stream, and with a narrow opening between its points, at the lower side of the sand bank. At this point, delvers jobbed or excavated a passage, and thus proceeded upward through the shoal. Their weapons were a common sharpened paddle secured to a stake or bamboo. The cut, once made, was soon widened and deepened by the operation of a known law of rivers; the superincumbent pressure of water being increased by the increased artificial depth in the first instance, and the energies of the river always seeking a new channel, being guided into one excavated for it. In this manner a barrier, which it would have been worth the while of the steam companies to remove at the cost of thousands of rupees, was effectually disposed of at an outlay of about Rs. 27. Major Hill's apparatus, simple as it has been represented to be, is susceptible of improvement. It could not, I understand, be moved without delay and difficulty; the delvers occasionally lost their footing, and had to swim. Whether this be correct or not is no matter. Major Hill's plan was good, and the experiment completely successful. I have attempted, in the inclosed rough sketch of what may be called a *movable bandel*, to convey an idea of the plan which succeeded; and the additions I would suggest, are two boats securely anchored, at a distance from each external angle of the cone, with hawsers communicating to the hindermost boats. With these, and a crew in each, the apparatus could be hauled up stream, or allowed to drift, as necessary, while life gaskets, or bits of rope, tied to a pole securely fixed transversely of the foremost, would enable the workmen to secure themselves from being carried away by the stream while delving and loosening the shoal. The only essential point to be observed, as a preliminary to operations, is to ascertain precisely the direction of the under-current. It can always be discovered with sufficient accuracy by throwing a cylindrical piece of light wood vertically into the stream, and noting carefully the direction in which it rises to the surface.

Movable bandel requisite in this portion of the line.

11.—The firm sand shoals, which occur in the portion of the river under consideration, it is thus argued, may be overcome by movable bandels with the means of delving. And the singularly small cost of such undertakings has been shewn by Major Hill's felicitous experiment.

The Bulleeah flats, extent, peculiarities, phenomenon, and conjectural explanations of them.

12.—We come now to the third portion, in which there is an obstruction of peculiar difficulty, which may be called the Bulleeah flats. What the natives call the *Bulleeahka-panee*, and the commanders of steamers, "bad water," is certainly not less than sixteen miles. The stream of the Ganges throughout this extent is a race through shifting sands. It is impossible by external indications to ascertain the principal or the practicable channel; continual sounding and slackened progress, are continually defeated by the suddenness with which the drift of sand terminates. Not unfrequently, the wearying process is necessary of warping the vessel over a series of shoals. The mutations, too, of positions of these obstacles, are extraordinary, not only for their extent, but rapidity. The knowledge of the pilot, obtained by labour and observation, is liable to be frustrated by a sudden shift of sand within the period of a few hours. There is, moreover, no little danger, of the vessel being susprized in the progress of those changes; of its being enveloped

in accumulations of sand overmastering the exertions made to extricate it; and of thus being imbedded in a sandy prison till the river volunteers some surprising change, or the return of the rainy season floats the vessel beyond the reach of its enemy. No satisfactory explanation has, I believe, been given of this phenomenon. The natives content themselves with assigning, as a reason, that a superabundance of *bálooh*, or sand, is washed yearly into the Ganges, from the surface of pergunnah Zumaneeah on its right bank, and Bulleeah on its left. The course of the river does not appear to have undergone any striking change, during the last twenty years; for, on comparing Colebrooke and Prinsep's map (above alluded to) with that of the recent survey, except a recess from the town of Bulleeah, and the appearance of a large alluvion called the Oomurpoor Dearah, right of the main stream, (instead of left as before,) no variation is perceptible. There may be something in native superstition; and as some assign the Bulleeah obstruction to the malignant influence of the Kurmnassa, this is not altogether unworthy of enquiry. Certain it is, that, the main difficulties are between the junction of the Kurmnassa on the right, and the little Surjoo, which is believed by some to have been once the course of the great Surjoo, or Gogra, on the left. I have been told that there are sunken ledges of rocks intermediate of these points; and although, from the perplexing contradictions of native testimony, I am unable to fix them, I am inclined to believe their existence; for, their existence proved, would I think in great measure account for the peculiarity. It would be reasonable thence to infer, that the river, restrained in its under-current by such an obstacle, when precipitated over it into a soft sandy soil, would exhibit the present peculiarities of increased rapidity, in certain parts of its course in whirlpools, eddies and shifting sands; which separately, or altogether, make the Bulleeah waters so difficult a part of the river navigation.

13.—One of the remedies suggested to rectify this evil, is, to cut a canal along the chord of the arc, which represents the river's present course, from Bhurowlee in the Ghazeepoor district on the left bank, to Doobowlee on the right, in the Ahrah district; and here it may be remarked, that the contour of the river at the Tonse flats (to be hereafter alluded to) is much the same as at those of Bulleeah; with the difference, that the Surjoo and Rewah Tonse enter the Ganges on opposite sides. A similar canal, in the latter case, would be projected from Dumah to Barrah. But we have the great authority of Rennell against such a measure. He has shewn that, wherever the soil is loose, the constant attempt of the river in a canal, will be to assume a serpentine course. Besides the extreme probability of every season closing the mouth of the canals with sand; there is his competent authority to assume, that the experiment would fail, owing to the yielding nature of the soil of the bank, on which bays or cavities would be formed; which, again, would beget an inflection of the current to the opposite side with the matter excavated left in its transit in the midchannel, and thus support the stream in the similar erosion of the opposite bank, with a similar result. Besides, it has been clearly shewn, that in those rivers, the least impediments are to be found, of which, by the exceeding sinuosity of the course, the stream is gentle. Diminution of the race of the Ganges on the Bulleeah flats, is the desideratum. Increased celerity, by curtailment of distance, would only magnify the evil.

Of remedies suggested; turning the stream by a canal either before Bulleeah or Sirsa, in the first portion of the line controverted.

14.—The probability of securing a permanent channel by dredging, with all the advantage of scientific apparatus and the agency of steam, is, I consider, very problematical; and it would be

Dredging; the success problematical and the application premature.

injudicious to recommend the trial of expensive means, until simpler expedients have been attempted.

Screen or hedge bandels proposed and described.

15.—Colonel Pew, with the commendation I believe of a very competent authority, Major Boileau, has suggested the trial of a simple apparatus. I do not know a better name for it than *screen bandels*. The principle is to induce the River, to assist in forming a channel and adhering to it. The different exhibition of sands, the greater extent, and the more difficult application of means, compared with the hard sand bank above treated of, renders a somewhat different process necessary. These bandels must necessarily be of greater length. The apparatus will consist of a fleet of Boats, at some distance from each other, in two lines; with ropes to each, stakes at intervals, and hawsers passing from end to end, to which will be fastened bunches and bundles of the common Bhyr koonta, (or Palla thorn bush,) which will be imbedded in the sand. The shallowness of the water will render this easily practicable. The course of the stream will have been previously ascertained; and the effect of judicious location of the lines of bandel, will be to induce an inflection of the current, from the one to the other, so that eddies may be formed behind the screen in which the sand will be deposited, while the current (with or without aid) clears the intermediate channel. This process it is considered will both effect a channel for, and indicate it to, the navigator.

Recommendations for their use, their small expense, and facilities of procuring materials.

16.—These means are simple and inexpensive; and the perfect success, which attended Major Hill's experiment last year, is sufficient argument that they should be tried. I recommend their trial. The material is at hand; both sides of the river have abundance of Dinghees and Mullahs; country rope and twine, stakes or bamboos, and the thorn bushes alluded to, are procurable in any quantity.

Necessity of appointing a Superintendent to be located at Bulleeah ordinarily. His duties and occupations.

17.—But there must be a special agency, and it is important that it should be efficient. A Superintendent should be stationed at Bulleeah to supervise, with the aid of those immediately subordinate to him, the clearing operations, as the nature of the difficulty may require; and to institute a close and scientific scrutiny of the nature of the country, and the peculiarities of the River Ganges and its tributaries. This is not to be gained in a trip up or down, or a mere gallop over the fields. A series of careful levels should be taken; the variations of slope should be ascertained; the bed of the river should be minutely studied, especially in the vicinity of tributary streams; and the existence of supposed rocks, and such permanent barriers to the free course of the river, should be determined with notice of their effects upon the current above and below.

Bulleeah preferable to other places.

18.—Bulleeah is a suitable spot for the ordinary residence of the Superintendent, because of its approximation to the principal difficulty. Dwelling houses are available, and there is a regular post between the Tehseeldaree there, and Ghazeepoor. The necessary communication can thus be maintained; and, in emergency, assistance can be rendered by the district establishments, fiscal and police.

Aids to be given to the Superintendent from Government Offices.

19.—The Superintendent should be permitted to have free access to the records of the professional survey of the districts in the Benares division; and the Sudder Board of Revenue will be able to supply him with the district maps of Ghazeepoor, Benares and Mirzapoor. Doubtless, a map of the Shahabad district, may be obtained from the Commissioner's office of the Patna Division.

20.—The immediate subordinate agency should be Europeans. Such men can be obtained and replaced if need be, with the aid of Major Stewart from Chunar; each would have his allotted portion; his boat and crew; receiving orders from, and reporting to his superior, with their aid, bandels will be formed where necessary for clearing operations; dangers will be noted; and information obtained. It will be primarily necessary to impress upon these men that they must consider civility to all, and especially kind treatment of the natives, their most necessary qualification: rudeness or violence will lead to instant dismissal without appeal. This is more important than may at first sight appear. These men will come in contact with various classes of people; much of their usefulness will depend upon enquiries and consultations. They cannot be too strongly advised to conciliate alike the good will of the Captain of a steamer, and that of the half-naked native boatmen. In the employment of Europeans, there is, too, an assurance, that, no extortions will be attempted upon boats in transit.

His subordinate agency should be Europeans. Reasons why; and where obtainable; and what qualification particularly necessary.

21.—The Commanders of Steamers will, it may be assumed, readily give a free passage to the Superintendent up and down in his vocation, and allow his subordinates occasionally to attach their boats when proceeding up stream. Coloned Pew, the principal member of the Ganges Company, willingly accedes to this proposal. It may be enjoined by authority on the Commanders of the Government Steamers, much, I have hinted, depends upon free communication with these officers. It may be presumed that they will readily give all the information they possess, and attention to any obstacles they have encountered. It would be beneficial, if they recorded in their logs having made such communication; and the Superintendent should be allowed to make transcripts therefrom, of whatever may be useful for him to know.

Aid to be tendered by all Commanders of Steam Boats to Superintendent and Overseers; and record of their communications should be kept.

22.—The Government have in these two portions of the line, officers holding positions at or near the river, who need no call to take an interest in the measures recommended. The Magistrate, of Mirzapoor; Major Stewart at Chunar; Coloned Pew, the Magistrate and myself, for Sultanpoor and Benares; the Magistrate and the Executive Officer at Ghazeepoor, and Major Sherer, the Superintendent of the Stud at Buxar.

To whom the Superintendent and Overseers may look for countenance, and the Government for advice and interest.

23.—Of the proposed fixed establishment, a schedule is annexed. The contingent expenses will be, hire of boats and men for constructing the bandels. Such expenses, sanction obtained, should be generally paid by the Superintendent; and, with all accounts, may be submitted to this office for audit and examination. A monthly report of operations should accompany the monthly account current, and thereform extract should be made and submitted, of any thing new and interesting to Government.

Schedule of fixed establishment; what expenses will be contingent: checks.

24.—The Government may be able to provide an officer for the duty of Superintendent; but if not available, Colonel Pew is of opinion that a Mr. Lloyd, who has received the education of a Civil Engineer, and came out to this country, anticipating employment in the Railway undertakings and is at Lucknow, is a competent man for the post. The salary proposed is 400 Rupees per mensem; but with the assurance on the part of Government, that, if they are satisfied with this officer's industry, and successful application of his talents,

In the absence of a Government officer, Mr. Lloyd is recommended for the office of Superintendent: proposed salary.

not only to the practical operations, but the scientific researches above alluded to, it should be raised to Rs. 50 per mensem.

25.—Should the arrangements proposed meet the approval of Government, Mr. Lloyd (no other person being available,) should be directed to proceed to Allahabad, and to submit his professional knowledge to the examination of Major Boileau, whose report will determine the question of his appointment.

His appointment to be preceded by examination before, and certificate from, Major Boileau, Allahabad.

SCHEDULE OF ESTABLISHMENT.

Superintendent, ...	Rs.	400	
Writer, ...	,,	30	
4 Tindals, @ 4 Rs. each, ...	,,	16	
			446
5 Europeans, @ 50 Rs. each, ...	,,	250	
10 Tindals, @ 4 Rs. each, ...	,,	40	
			290
6 Boats and Crews.			
Boat Hire, ...	,,	5	
Manjee, ...	,,	4	
5 Mullahs, @ 3 Rs. each, ...	,,	15	
Oil, ...	,,	1	
		25 × 6 =	150
			886

Benares, the 25th August 1847.

POSTSCRIPT.

The Tonse flats, as far as I am able to ascertain, present difficulties of three kinds, kunkur beds, hard sand, and shifting sand. These occur between the village of Deeha and Sursa. The native explanation of the origin of these obstructions may not be very far from the truth; viz., that the river Ganges is more rapid than the Jumna, and carries with its stream a vast quantity of alluvial matter; that, though the upper stream of the Jumna is subjugated by the Ganges at their junction, the under-current of the former river is less affected; and that its agency prevents deposit for some distance, until, in fact, the Tonse comes into the main river, and checks its progress, which causes the precipitation of the alluvial matter previously kept in suspension. The kunkur bank is said to be the gift of the Tonse.

The Commanders of Steamers consider these obstructions infinitely more manageable than those at the Bulleeah flats. The peculiar impediments here presented are; ever varying channels of the main stream until the cold weather has passed, and a general shallowness of water, when the river has finally settled its course for the season. The larger steamers of private companies have, in consequence of this obstruction, made Mirzapoor their terminus, instead of Allahabad, during the greater part of the year. The Government steamers, which require less depth of water, can generally reach Allahabad; but not, I understand, without the necessity of warping over more than one shoal in the part of the river under consideration.

Doubtless their logs, if examined, would give some more practical information than they can be expected to communicate in reply to questions put in the bustle of

landing passengers and receiving cargo. I have learnt so little from them, and from enquiries amongst the native crews, that I can only recommend further enquiry. Major Boileau's residence at Allahabad will enable him to prosecute the necessary enquiries with infinitely greater chance of success from his vicinity to the spot, and his professional abilities, I doubt not his hearty consent to this division of labor.

The schedule of establishment, however, I should observe is fixed for the whole line from Allahabad to Revelgunge; and the Superintendent will, of course, make the Tonse flats the subject of his researches, and freely communicate with Major Boileau. In fact, I should recommend, that every record of scientific observations prepared by the Superintendent, should be submitted to Government through Major Boileau.

RIVER BREAK-WATERS.

Reports by MAJOR R. TICKELL, *Superintending Engineer, Lower Provinces, on the River, March 1829.*

No. I.—MUNDELAPORE.

The following examples of the successful application of sunken break-waters, composed of bamboos and brushwood, for the protection of river-banks exposed to the action of a strong current, eddies and wind, were lately communicated to me by Mr. J. Watson, of Furreedpore, proprietor of several indigo factories between Surdah and Commercolly. Amongst others, that at Mundelapore, about three miles above the latter place, where in 1823, he states that the Goorye had made such rapid encroachments on the bank in front of his factory, as to endanger the vats, between which and the edge of the bank in March that year, there only remained 15 feet, as shewn in the Sketch No. 1, *(vide Appendix)* when he laid down a break-water *A.* about 600 yards in length; that is, extending 500 yards above the vats and 100 yards below them, at the distance of about 15 feet from the bank: the rope on which it was formed, being secured to a stout bar of wood, buried 4 or 5 feet in the sand at *B.*

2.—The break-water was composed of large bamboos in their green state, with all their leaves and branches on, and branches of trees or brushwood, placed alternately; the first lashed on by the root-ends to a 4 or 5-inch rope, at 5 or 6 feet apart, and the branches secured in similar manner between, (*see Sketch* No. 2;) and the whole gradually sunk to the bottom, as it was constructed, and retained there by means of gunny bags, filled with sand, which were made fast to the rope above-mentioned at the distance of every 12 or 15 feet.

3.—I need scarcely add that the intention of the break-water thus described, was to induce the formation of a new sand bank in front of the factory, and by that means to throw off the current towards the opposite side, it being expected that the bamboos and brushwood offering little or no obstruction to the stream, would yet arrest and gradually collect around them, the sand, mud, and weeds, &c. brought down by the river. The result, it would appear, was more successful than could have been anticipated, and the state of the river in March the following year, is shewn by the dotted line; the bed having filled up along the line of experiment, and to a considerable distance below it, from 20 to 28 feet: and remains so to the present day.

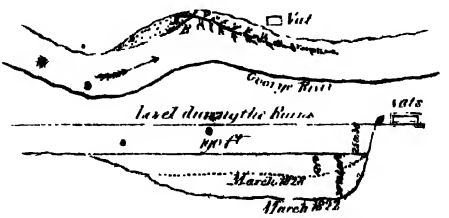
No. II.—MOZEMPORE.

The Mozempore factory [at the head of the Goorye River opposite Coosteah] also belongs to Mr. Watson, and in 1824, the vats were found to be in a still more dangerous state than those before-mentioned at Mundelapore, being undermined so much in some parts, as to admit of the bottom of the foundation being seen from below. As in the former case, Mr. Watson had recourse to the sunken break-water, and with similar success, the bed of the river in front of his factory having filled up in the course of the following and succeeding years, as shewn by the dotted lines in the Sketch No. 3.

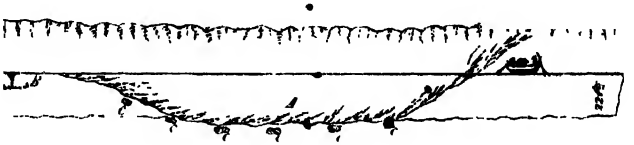
2.—In this instance, however, he substituted a chain of bamboos, fastened one to the other, for the rope to which the floating or vertical bamboos, brushwood and sand bags were lashed on as before described.

N°1

Mundelupoor Indigo Factory near Commercolly



N°2



A The Breakwater put together on a couple of Dingies connected by a Bamboo platform

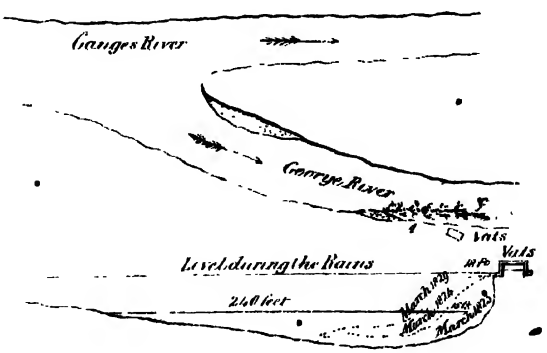
B Wooden bar or branch buried 4 or 5 feet in the sand to which the Breakwater is secured.

C C The sand bags

N°3

Mozempoor Indigo Factory

At the head of the George River opposite to Goosteah



Printed at the Secundra Orphan Press

3.—A considerable part of the bank above the vats at *A.* had been excavated and swept away by eddies, as also several other parts higher up, although in a less degree. The bottoms of all these hollows, to a level nearly with the water, were covered with large branches of trees and brushwood, secured by stakes driven in between, and the head of the break-water was made fast by a rope to a bar of wood buried 4 or 5 feet in the sand at *B.*

4.—As an additional security, and to prevent the break-water from being carried in towards shore, when first laid down, Mr. Watson recommends its being anchored to 2 or 3 sand bags as shewn at *C. C. (Sketch No. 2);*—a precaution particularly necessary when floating break-waters are used; which are constructed in the same manner, of bamboos lashed together; and form a good defence to a high precipitous bank, exposed in stormy weather to the destructive effects of the waves beating up against it by breaking their force, and allaying the motion of the water in shore between the bank and break-water, however rough it may be on the outside.

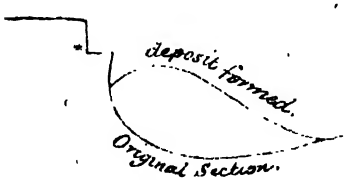
BREAK-WATER IN THE JUMNA, AT AGRA.

Letter from CAPTAIN J. R. OLDFIELD, *Executive Engineer, to* P. B. REID, Esq., *Secretary to Local Agents for the Management of Nuzzool Funds, Agra, dated Agra, the 28th August 1847.*

SIR,

Having completed the measure, suggested by me to the Local Agents, and authorized by Government, for keeping the strand road under the Fort at Agra from being further cut away by the action of the stream of the Jumna during the present rainy season, I have the honor to forward a statement of the expense incurred, and to report, that along the portions of the strand protected by a chain of bushes, not only has a particle of the bank not been washed away, but that I have reason to hope, that throughout its length, about 1,800 feet, a bank of alluvion has been formed, varying in breadth from 10 to 30 feet, and in depth from 5 to 6 feet.

The part protected is from the Shah Boorj of the fort to below the water gate. The section of the bank, nearly throughout this length, showed in a marked manner the effect of the stream on it last year; being much indented, and nearly perpendicular: which is the form in which the alluvial banks of large rivers in their outer bends are usually left whilst the process of encroachment is going on.



It will probably be observed, that the portion of the strand road, which lies below that which has been defended, has not suffered injury any more than that which has; but the inference must not thence be drawn that the defence was unnecessary; I need only draw attention to the differing section of the strand, and the differing direction of the stream of the two places. In fact, the parts undefended seemed to me safe, and I proposed only to defend those along which the line of bushes has been laid.

The river having been late in rising, I had, though I commenced work late, time to lay down the row of bushes before the water rose to the foot of the perpendicular portions of the bank on which I feared the action of the stream; and when it did rise, I had the satisfaction of seeing that the bushes produced perfectly still-water in the space between them and the bank; and that the stream in place of cutting away the foot of the latter was entirely turned by the line of bushes. This still-water naturally produced a deposit, which on the falling of the water after the rains may easily be measured.

Besides protecting the bank for the distance above stated, I have laid a double row of bushes in the stream across the embayment formed by the total breach of the strand, at its eastern extremity where it meets the inland road to the Taj. This row is laid in deep water, but I expect when the river falls to find an unbroken bank of 5 or 6 feet high along the line of bushes, leaving a pool within them unconnected with the stream, which may be filled up in the cold weather, and the strand once more connected with the road to the Taj.

Besides these two more extensive lines of bushes, I have in some degree protected the bridges on the line of the strand, which seemed in great danger of being left isolated, and probably suffering considerable injury.

The stream this year has, I should suppose, been both lower and more tranquil than usual, and my precautions for keeping the line of bushes from being carried away have been greater than necessary. I have used throughout two ropes of moonje grass, each measuring 2½ inches in diameter, and frequent anchors of heavy stones, whilst from the rapid setting up of the bed of the river where the bushes are laid, they get so soon clogged thereby, as to render them little liable to disturbance, specially as they offer at first but little resistance.

Of one thing I feel almost certain, that bushes anchored with their branches pointed towards the source of a stream holding much earthy matter in suspension, will form banks at any points required, and these may be added to, annually, until they reach the highest water level.

In conclusion, I have the honor to observe, that the strand road has never been completed; that for a considerable distance it is too low, and is rendered lower annually by want of a sufficient number of culverts across it, to drain its surface water from its inner edge: and that a great quantity of earth-work is required to replace that which has been washed away at the parts protected this year, and at the several bridges over streams crossing the strand.

The best protection to the strand would be a line of well built ghâts, and considering how the river is held in honor by the Hindoo portion of the population, and how important a good quay is to all the commercial people, I hope, that some of the wealthy inhabitants of the city of Agra may be induced to supply this desideratum at least partially.

In the meanwhile it will be advisable to plant the sloping bank, lately acquired by deposit from the stream, with jhow, as soon as it is left dry by the receding of the river; if this is done, three or four culverts built, and the road restored at the bridges, and at its eastern extremity, I think it will remain, much in the state to which it was originally brought, for many years to come, especially if timely petty repairs are made as occasion may require.

Letter from CAPTAIN J. R. OLDFIELD, *Executive Engineer, 10th Division, to the* SECRETARY *to the Local Agents at Agra, dated 30th September 1848.*

SIR,

In sending you again the plan and estimate* submitted in December 1847 to the Local Agents at Agra, I have the honor to state that no portion of the ground gained during the rains of 1847, by protecting the bank of the strand with bushes, has been lost this year, and that the three short spaces filled up in the beginning of 1848 have had an excellent effect in widening the base of the strand, to admit of its being widened at top.

This base might have been easily widened still more, by putting the bushes further out, but I was anxious to preserve the wharf, as well as the road, and therefore to keep comparatively deep water along the strand, especially under the Fort.

This year the principal force of the stream has been thrown on the bank between stations marked *2 and *3 (in the plan,) and this portion consequently received further protection at the beginning of the rains.

* Omitted in print as not requisite.

At the point where the strand joins the Taj road, which was completely broken through, an excellent base has been obtained, now well above water, for restoring the communication above high-water mark.

The importance of the strand and wharf, so far as it lies under the Fort walls in a military point of view, led me to bring the subject under the consideration of the Superintending Engineer North Western Provinces, on the occasion of his visiting Agra lately, and under instructions from him, I am now preparing an estimate for raising and repairing the portion lying between *1 and *16.

The estimate, however, does not include a metalled road, which is left for future consideration.

* Omitted in print as not requisite.

BRICK-MAKING MACHINES AT ROORKEE.

I.—MEMORANDA *on* HALL'S *and* AINSLIE'S BRICK-MAKING MACHINES, *as used in the* ROORKEE BRICK FIELDS, *by Lieut.-Colonel* P. T. CAUTLEY, *Director Ganges Canal Works. Dated Mussoorie, the 29th April 1850.*

The masonry works on the Ganges Canal in the immediate neighbourhood of Roorkee, a town situated 23 miles E. S. E. of the town of Saharunpoor, required for their completion in round numbers, 1,000 lakhs of bricks, measuring 12″ by 6″ by 2½″; the period fixed for the completion of these works was six years: a quantity of bricks therefore equal to 166 or 170 lakhs was required annually.

2.—Without entering into a detailed statement of the arrangements made for the manufacture of so much material, the collection of so much fuel, or the concentration of such large bodies of laborers at a point near the Sewalik forests, and in a country whose inhabitants are chiefly agricultural, it may be sufficient, with reference to the heading of this memorandum, to draw attention to the mere difficulty of procuring in sufficient abundance, *brick-moulders*, or men to make and mould the bricks, previously to their being placed in the kilns.

3.—The brick-making season is from the 1st October to the 15th of June, and (deducting Sundays and rainy days) two hundred days in each year may be considered a maximum working period. Supposing, therefore, that each brick-moulder made 800 bricks per day, one hundred and five men per day would be required to make the number of bricks required for the Roorkee works.

4.—To collect so many brick-moulders, and maintain them constantly at work, considering that their services were not required for three and a half months in the year, was a matter of very serious difficulty. To be utterly dependent, on a class of people, moreover, who absented themselves whenever it suited their convenience, and, who, knowing how dependent we were on their services, took advantage of their ability to cause interruption by repeated *strikes*, was an evil of very great magnitude; it was an evil in fact that machinery alone could get rid of.

5.—During my visit to England in 1846-47, my attention was constantly directed to this point. The tile machine, invented by the Marquis of Tweedale, and other apparatus both for tile and brick-making, were fully appreciated in Europe. Mosul Bey, the French Engineer on the Barage on the Nile, where three brick-machines were at work, had shewn me bricks made by this machinery. The question for me to determine was, the applicability, or not, of machinery of the sort above alluded to, to our works situated at a great distance from a foundry, and at that time from all practical mechanical aid. In all my enquiries in England, I was universally referred to Ainslie's brick and tile machinery. It appears to be in common use, and is exceedingly simple, both in principle and construction. In the manufacture of either bricks or tiles, the clay, which has been properly prepared and tempered, is passed through iron rollers, and from these through upright moulds of the form that the brick or tile is to be made. The moulded clay as it then comes out of the latter is cut off by wires into the lengths required. This machine is made of cast iron, with iron spur-wheels, the breakage of which in the upper provinces of India would lead to inconvenience. Its simplicity appears to have recommended it to the English brick-makers, but the chance of breakage, and the difficulty of replacing cast iron wheels

at a distance from a foundry, were in some measure opposed to its success at a remote province in northern India.

6.—As the appartus however had stood the ordeal of much use in England, and was highly recommended, I thought it advisable, to ensure progress, to direct two of these machines to be sent to Roorkee, and I did this with greater confidence, as I found that the loss of a few teeth in the spur-wheels did not affect the proper working of the machine, and that by supplying myself with spare wheels the chance of disappointment was small.

7.—Up to the present period, however, we have totally failed in succeeding to get good bricks from this machine of Ainslie's: we have spared neither time nor patience in endeavouring to detect the cause of failure, and I have come to the conclusion, that the quality (a point that we shall by practice be able I hope to rectify) of the clay used at Roorkee is not capable of retaining its form under the process required by this machine: clay of every consistency, as regards moisture and tempering, has been tried without success. Mr. Scrivener, the manager in England, writes through the Secretary of the Company, that "I am sure however, it will do when the "nature of the clay is well understood; the fault of the brick being larger on the "bottom can be remedied by taking out the intermediate rollers, and substituting a "plain board covered with a cloth; and if it comes out rough on the upper side, you "must put a piece of wood at the back of the die to hold the clay back, thus forcing "it to the corners; this I have done with some clay, and always found that it had "the desired effect."

8.—The circumstances alluded to in this Extract, are those which I pointed out as the results of our trials, viz. that the clay in passing through the die, or former, was torn and disfigured at the edges, and that the brick itself lost its rectangular form in passing from the die upon the rollers. The latter circumstance evidently arises from the weight of the soft and unsupported material. Laying aside the tearing of the edges, the shape of the brick as turned out from Ainslie's machine in the Roorkee manufactories is thus:—the dotted line shewing the die or hole through which the clay is forced,

FIG. 2.

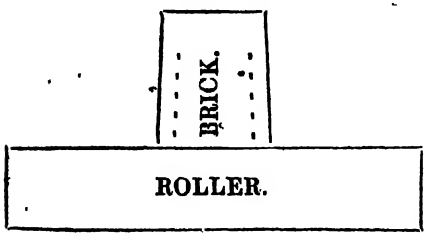


FIG. 1.

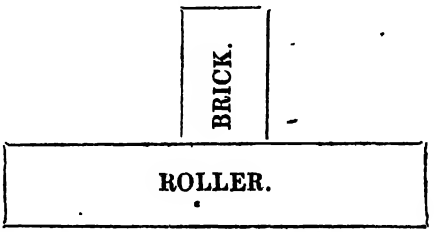


Fig. 1 shews the true form that the brick ought to assume on leaving the die.

Fig. 2 that which it takes in practice.

Figure 2 is admirably adapted to the voissoirs of small segmental arches, and the bricks so made may be turned to account in the construction of drains and culverts.

9.—Mr. Finn is now engaged in making further trials with this machine; and I hope that his endeavours will be crowned with the success that he deserves.

10.—When inspecting the machinery exhibited at the agricultural meeting at Northampton in 1847, I observed a brick-machine bearing the inscription of "Hall's

Patent." After further enquiry and proceeding to the Patentee, Ransome of Ipswich, at which place I visited the brick-fields where the machine was used, I was so much struck with its simplicity and aptitude for use with our native laborers, that I ordered one to be sent out to India. The accompanying reports and tables submitted by Mr. Finn, the Executive Officer of Materials, at Roorkee, exhibit the results of operations with Hall's machine during the working season of 1848-49, accompanied by a copy of the printed advertisement, and drawing of the apparatus as received from Messrs. Ransome and Co. The progress during the present year, 1849-50, has been equally successful.

11.—The description of Hall's machine, which is I believe an American invention, is given in full in the accompanying papers. It may be described thus:—

The clay, properly tempered, and worked up in a large reservoir attached to the pug-mill A, passes through the mill into a tray B, consisting of moulds for five bricks. This tray B, is pushed in by hand, (as shewn on the left of the sketch,) and rests upon a platform with horizontal motion gained by the use of the wheel C. By this wheel C, the tray, when filled with earth from the pug-mill, is pushed forward, until it comes into position under the pressing apparatus, the pressure being gained by the downward movement of the lever D. The tray being relieved from the pressure, is taken out by the hand from the front of the machine, and carried to the drying ground, where it is emptied and brought back again for further work. This process goes on as rapidly as trays can be supplied.

12.—In bringing a machine of this sort into use with our native establishment, it was natural that interruption should take place in the commencement. Mr. Finn, however, had taken the precaution of drilling a party of bildars into the motions of the machine for some time before he allowed bricks to be made with it. Brick-making therefore was commenced with very tolerable expertness; and, with the exception of slight delay from occasional breakage to the machine, and from time required to gain experience on the proper state of moisture, in which the clay was to be supplied from the pug-mill, the machine has proceeded steadily at its work. It will be observed that the number of bricks turned out daily, from the period when tolerable practice had been gained, averages 10,000, with a maximum of 11,670; an amount fully equal to that held out in the advertisement.

13.—In the Roorkee fields twenty-eight men and four bullocks per day are employed. This establishment includes excavating, watering, and carrying the mould to the pug-mill reservoir, in addition to the working of the machine. The establishment noted in the prospectus, as used in England and America, of one horse, two men and two boys, can hardly include the labor required in digging and preparing the earth. We have found bullocks preferable to horses, and use the former accordingly. In all other respects the manufacture of bricks is carried on exactly as it would be in an English brick-field.

14.—The size of the brick is 9″ by 4″ by 3″, the same as used in England. We have succeeded in burning them sufficiently, and the massiveness of their proportions, secures them from breakage, which is an evil that we greatly complain of, in 12″ by 6″ by 2½″ or 2″ bricks, which we have been in the habit of using.

15.—The cost of bricks as turned out by Hall's machine is Co.'s Rs. 54-12-2 per lakh, a rate that will in all probability be reduced. The cost of making the larger brick has been Co.'s Rs. 91-0-10 per lakh. The cost of the machine in England was £96, and the total cost at Roorkee Co.'s Rs. 1,561-8-7.

16.—In consequence of the great success attending upon the use of this machine, we have made* two others in all essential respects similar. One of these is at work at the Mahewur brick-fields, on the left flank of the Solani aqueduct; and the other at Dhunowri, where the Rutmoo works are in progress.

17.—A reference to the tables which accompany this paper will bear me out in my opinion, that the value of this machine is established, as a most efficient and useful accessory to a brick manufactory in India.

No. II.—Report, *by* Mr. James Finn, *Executive Officer, to* Lieut.-Colonel P. T. Cautley, *Director Ganges Canal, dated Roorkee, 25th June 1849.*

Sir,

I beg leave to enclose herewith an abstract of the work people employed, and of the number of bricks made daily by Half's Patent Machine.

2.—The machine was set up in October 1848, and placed in charge of Serjeant Durrant, whose first object was to learn to work it himself; this he very soon accomplished, and he then taught a party of bildars how to use it; but owing to the stupidity and awkwardness of these men, the machine was continually breaking for the first six months after it was set in progress; the frequent stoppages to our work on that account were very disheartening: nevertheless, Serjeant Durrant preserved in his endeavours to give the machine a fair trial; he encouraged the bildars, with whom he occasionally took a spell at the wheel, and the results have been, that we had the satisfaction of seeing it work on steadily for the last three months, and of counting 11,670 bricks made by it in one day, which is about equal to the best turn-out obtained in England or America, from a similar machine.

3.—The bildars employed on the machine were placed in the following order, viz:—

11 excavated the clay and carried it to the pug-mill cistern, average distance 130 feet.
2 supplied the cistern with water, and cleared up the drying ground.
3 filled the pug-mill from the contents of the cistern.
1 cleaned and sanded the moulds preparatory to passing them into the machine.
1 served the machine with empty brick-moulds.
1 on the wheel pressed the mixed clay into the moulds.
1 on the river forced out the mould.
1 on the mister or strike, cleaned top of the bricks, and raised the moulds to heads of the carriers.
6 carried the loaded moulds from the machine to the drying grounds.
1 relieved the carriers of the moulds, and placed the bricks in regular lines on the drying ground.

Total 28 bildars.

4.—The size of a machine-made, unburnt brick is 10″ by 4¾″ by 3½″=148½ cubic inches. For 11,000, of these about 920 cubic feet of earth is required; therefore each of the eleven bildars employed on excavation, &c. had to dig, pulverize, and carry to the pug-mill cistern, about 90 cubic feet of clay.

* A machine of this kind made at Roorkee cost about Rs. 500.

5.—Bricks made by the machine for the last month have cost on an average Rs. 54-12-2 per lakh; and the rate of our bricks with the hand on pucka terraces at Roorkee, during the same moulded month (May 1849) was Rs. 91-0-10 per lakh; pay of the bildars, &c., for Sundays, in both cases included:—size of the last-mentioned brick 12½″ by 6¼″ by 2⅝″.

6.—In the yearly part of the current month, twenty-eight bildars at four rupees, with four bullocks at five annas each, made on an average 11,046 bricks per day by the machine, and at the same time to make 11,200 moulded bricks, the following were required, viz.

Moulders, @ Rs. 6 per month,	-- --	14
Bildars, @ Rs. 4 per month,	-- --	39
	Total	53 men.

7.—At the commencement it was attempted to work the machine by horses; but they were found not to answer so well as bullocks. Four of the latter animals were employed daily cutting and mixing the clay in the pug-mill;—two bullocks worked from sun-rise until noon: and two more from 2 P. M. until dusk of evening.

8.—Consequent on the many times the machine was broken, we had made by it only 9,76,016 bricks in the past working season; nearly the whole of these have been stacked into a large native kiln, which is at present being fired. Some pucka bricks, however taken out at its mouth, seem close-grained, compact and strong.

9.—I beg to add, that I have not included the expense incurred on repairs of the machaine, in the cost of bricks produced in the accompanying Abstract.

No. III—*Abstract of the Work-people employed, and of the No. of Bricks made monthly at Roorkee, by Hall's Patent Machine.*

Month.	No. of days work.	Bildars, at 4 Rs. per month.	Bildars, at Rs. 3-8 per month.	Chuprassees, at 5 Rs. per month.	Horses, at 5 annas per day.	Bullocks, at 5 annas per day.	Bricks made in the month.	Cost of labor. Rs. A. P.	Cost of sundries. Rs. A. P.	Total cost. Rs. A. P.	Average cost of Bricks per lakh. Rs. A. P.	Remarks.
October 1848, ...	9	79	——	9	10	——	12795	15 12 10	4 10 11	20 7 9	160 1 6	
November „ ...	17	52	307	17	24	32	65960	63 1 4	5 3 9	68 5 1	103 9 2	
December „ ...	4	20	92	4	6	10	15170	18 9 9	0 0 0	18 9 9	122 10 9	
January 1849, ...	18	444	——	16	——	48	89290	77 5 2	1 14 2	79 3 4	88 11 4	
February „ ...	8	203	——	——	——	24	45210	37 10 3	2 6 3	40 0 6	88 8 9	
March „ ...	12	307	——	——	——	40	86890	53 10 7	2 3 8	55 14 3	64 5 2	
April „ ...	30	786	——	——	——	88	218441	136 4 9	9 12 6	146 1 3	66 14 0	
May „ ...	31	868	——	——	——	108	287410	149 12 0	7 9 10	157 5 10	54 12 2	
June „ ...	17	476	——	——	——	56	154850	83 3 9	0 6 0	83 9 9	53 15 11	
							976016			669 9 6	68 9 8	

JAMES FINN, *Executive Officer of Materials, N. D., Ganges Canal.*

Roorkee, 23rd June 1849.

Note.—Half pay for a Tindal at Rs. 8 per mensem charged all through.

No. IV.—Mr. James Finn, *Executive Officer of Materials, N. D., Ganges Canal, addressed to* Lieut.-Colonel P. T. Cautley, *Director Ganges Canal Works, dated Roorkee, 7th May, 1850.*

The following circumstance is I think, well worthy of being noticed in your forthcoming report on the manufacture of bricks in the Northern Division of the Ganges Canal.

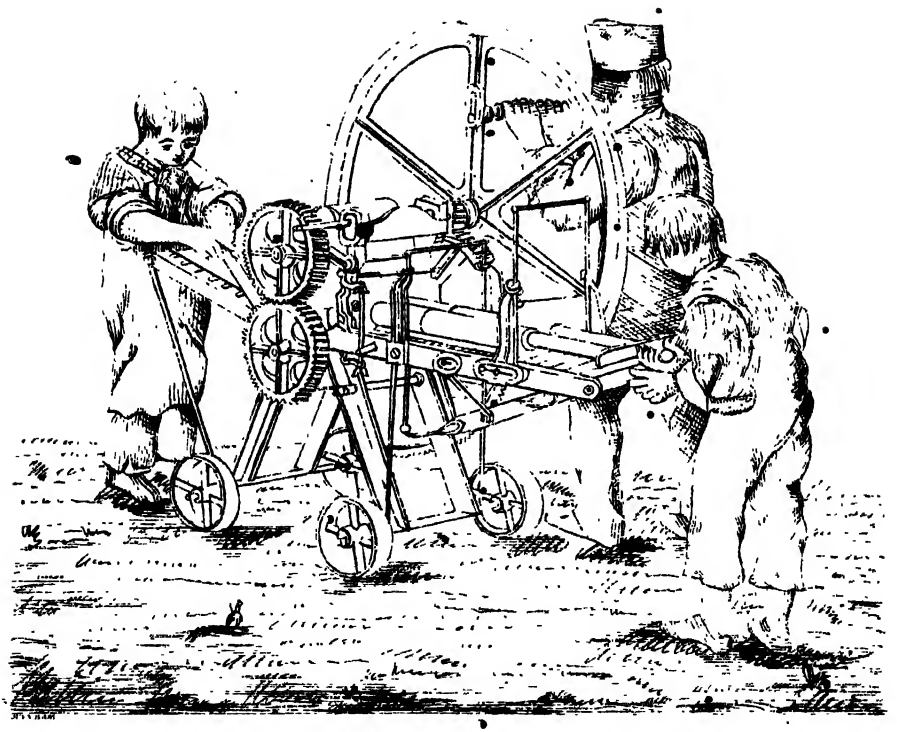
2.—Previous to the setting up of the first (Hall's Patent) machine, brought out by you from England, the brick-moulders were the most untractable and troublesome class of men on our works. We had then about 150 moulders employed daily at Roorkee and at Mahewur, and their combined and frequent efforts to evade the doing of a fair day's work, or to extort from us a higher rate of pay, caused much anxiety to all concerned in the manufacture of bricks. If an attempt was made to coerce a moulder, or even if fault was found with the quality or quantity of work performed by one or more of them, the whole would quit working collectively, take their moulds in their hands, and walk off to their huts, in spite of all remonstrance. I can well remember that they served us in this manner twice in one week at Roorkee. But since the machine has been erected, and the moulders saw us turn out from 10,000 to 11,000 bricks daily, quite independent of their aid, from having been the most unmanageable, they have become the most docile of all our work-people. At present we have about 200 brick-moulders employed at Roorkee, Mahewur, Dhunouri and Suleempoor: each moulder formerly made between 700 and 800 bricks on our terraces, and at present every man turns out 900 very superior ones, such as you have seen on all our brick fields, in the course of your late inspection. The pay of each moulder formerly, who did what was then considered full work, average Rs. 6-8-0 per month; at present we pay Rs. 6 only, and the whole of them work on cheerfully and steadily. Taking all this into consideration, I am of opinion that our possession of "Halls Patent Brick-making Machine" has proved an immense benefit to the works.

No. V.—*Extract from the description of* Ainslie's *Brick-making Machine, by* Wm. Gordon, *Secretary of the Company of Patentees.*

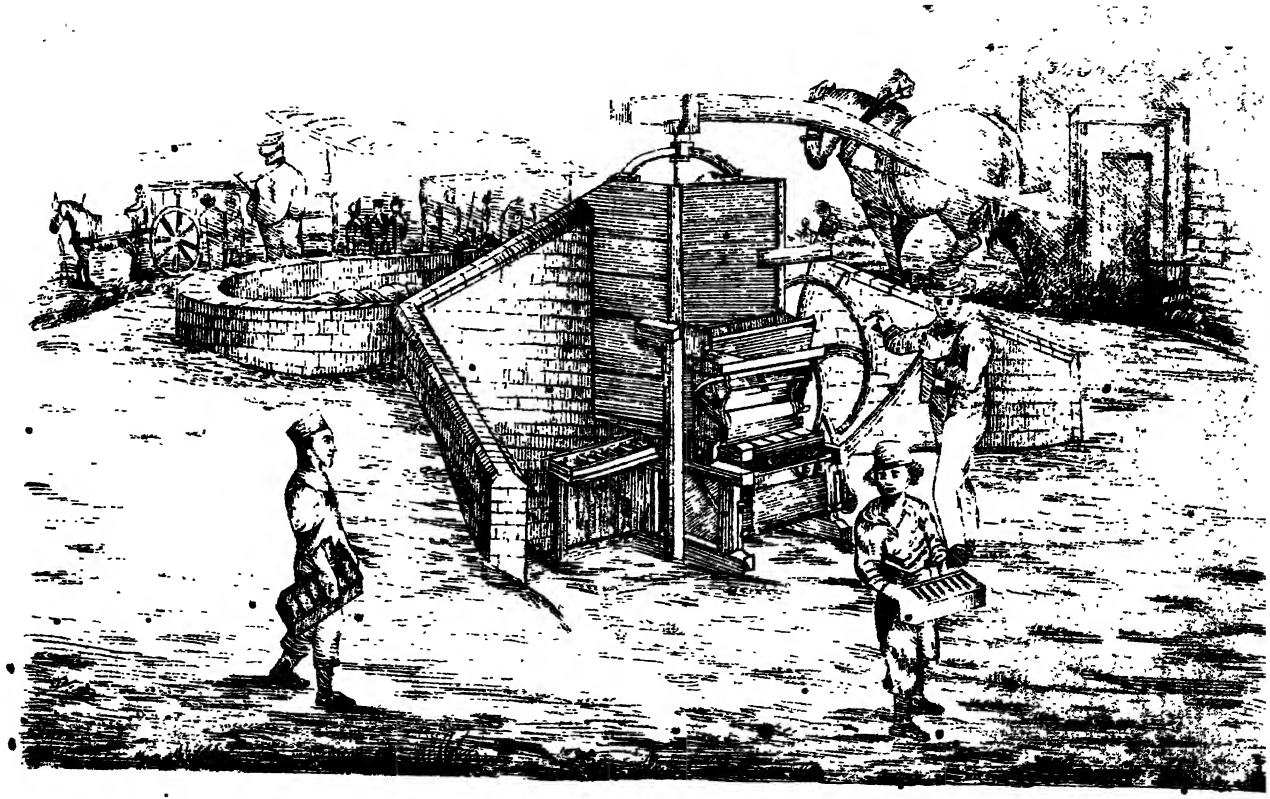
By these machines, (for which prize gold-medals were given by the Royal Irish Agricultural Society, at their meeting at Balinasloe, and by the Highland and Agricultural Society of Scotland, at their meeting at Dumfries, and also at Inverness,) draining tiles and pipes of the most perfect form, are produced at a much cheaper rate than by any other machine hitherto invented.

The peculiarity of these machines, is that a continuous stream of clay passes between the cylinders, and presses through the dies in the most perfect manner, pipes, tiles, or bricks of any form; and the apparatus is so arranged as to cut to any length and perfectly true. They can be driven equally well by steam, horse, or hand-power.

The machines are so simple in their construction, that with common care, they cannot get out of order, and any country-mechanic can easily repair them; and they are the only machines by which the hollow brick, so highly approved for building and horticultural purposes, can be made. The quantity of bricks or tiles made, depends upon the speed at which the machine is driven, varying from 4 to 15,000 per day.



AINSLIE'S BRICK MAKING MACHINE



PRICES.

	£	s.	d.
A hand-power machine, including two moulds or dies,	30	0	0
Additional dies, @ 10 shillings each.			
A horse, or steam-power machine, including 2 dies,	50	0	0
Additional dies, @ 15 shillings each.			
Horse-power for ditto, -- -- -- -- -- -- -- --	25	0	0
A machine for making solid bricks complete, which will turn out from 10 to 15,000 per day, of 10 hours, --	60	0	0

No. VI.—*Extract from the description of* HALL'S PATENT BRICK-MACHINE, *manufactured by* FREDERICK RANSOME, *Ipswich.*

The following particulars are copied from an American paper, printed at New York, relating to a brick-machine, for which Mr. Frederick Ransome, of Ipswich, is the Patentee for England. The machine can be seen at work at the Patentee's, Flint Wharf, Ipswich.

The engraving represents a machine for making brick, patented in the United States and Great Britain, by Alfred Hall, of Perth Amboy, New Jersey; showing a pit in which the clay is soaked, the mill for grinding it, and a moulding machine as attached when in operation.

The most recent and approved method of constructing a brick yard is as follows:—

The yard should be graded so as to extend from the clay bank one hundred and fifty feet, nearly fifty feet being cut off from the side opposite the clay bank for kiln-ground; the part between the kiln-ground and clay bank, being the drying floor, should, if not made upon a clay foundation, be faced with clay, made smooth and solid, and sufficiently inclined to carry off the water immediately after rain. On the side of this floor next the clay and opposite the kiln-ground are placed the pits, or vats, in which the clay is soaked. These should be equal in size to one-half of a circle nineteen feet in diameter, and three or three and a half feet deep, made water-tight, and either of wood or brick (according to climate and convenience), the front or machine-side being on a line with, and facing the drying floor, and placed at distances, each to occupy or accommodate from sixty to eighty feet of the drying floor; the bottoms of the pits are on a level with the drying floor: consequently they rest on an embankment near three feet higher than the drying floor. At the centre, and in front of the pit, stands the grinding mill, a plank box resting on a solid foundation, six inches higher than the bottom of the pit; it is three feet four inches square, and four feet high, projecting fifteen inches over its foundation, so as to permit a portion of the moulding machine under the front of it. In the centre of this box is an upright shaft, in which knives are placed, and on the top of which is the sweep or lever, to which the horse is attached; at the bottom and in front is an opening for the mortar to pass into the chamber of the moulding machine. The bottom of the frame of the moulding machine will stand about two and a half feet lower than the drying floor. The horse-path will be thirty-two feet in diameter, (the sweep being sixteen feet from the upright shaft to the place of attaching the horse), passing round the pit and all the machinery, inclining three feet from the back of the pit to the drying floor in front, from which point an inclined plane is graded down to the bottom

of the moulding machine, for the convenience of off-levers in going to and from it. A box containing sand for moulding is placed near and at the left of the machine.

The clay, unless it is soft like putty, or dough, works best generally to plough and dry it, putting the water in the pit first. The dry clay is then shovelled in—not in heaps, but scattered so that every shovel-full shall go into and under the water, scattering the clay continually in the deepest, and using up the water, and rising above it only when the pit is full. It is left thus to soak over night, when it is ready to grind.

Having thus prepared the yard,—with the kiln-ground on one side and the machine on the other, the drying floor between, and a vat containing water convenient to each machine to soak and wash mould in, and having dried and sifted through a fine sieve a quantity of fine, sharp sand (the particles pointed and flat), for moulding,—we are ready to commence work. It is the work for one man to shovel the clay from the pit into the grinding mill; he adds a little water in the mill, as it may require; keeps in as even temperature as possible; keeps the mill full, and the horse in motion. The mortar passes continually, as it is ground, out of the opening in the mill, directly under a revolving press, into the chamber of the moulding machine, at the bottom of which is a grate, under which rests the mould, on rollers, in front and rear of which are grates; the pales and rollers, forming the top of the main carriage, the sides of which are kept about one inch from the plates by steady pins, which serve also to keep them from oscillating, and having (at their rear end at the outer edge) iron rails, the whole being constructed so as to allow all surplus sand and rubbish freely to riddle through. It is supported in rear by a girt, suspended from the plates by screw-bolts, the front resting on rods connected with a shaft, to which is attached the lower small lever, which, being drawn forward, instantly drops the front of the carriage, and releases the moulds from obstruction by stones or otherwise. On the iron rails runs a movable carriage and an axle having wheels to run on the rails, to which is attached a crutch lever, curving so as to connect with the axle, thence passing forward is connected with an arm or lever extending to a shaft below, to which is attached the large lever, which attaches this movable carriage, so as to force the empty mould under the chamber, and the full one out on to the front of the carriage. The upper small lever operates the press by means of a shaft with pinions operating in segments.

The operation of moulding is simple. The mortar passes directly from the grinding mill, in a confined state, into the chamber of the machine through the grate into the mould. The press lever is then brought forward, pressing sufficiently to fill out the corners, the pressure being kept on till the mould is filled and started by means of the large lever. As soon as the full mould starts, the press lever is let go, and when the mould is drawn out, both the levers are replaced, ready to repeat the operation. The moulder then smooths off the upper surface of the brick, by drawing a strike (the mettle edge of which may be wet in the small box in front of the larger one resting on the machine) across them, cleaning off the box; the lower lever is used only to drop the carriage when the mould is obstructed, and then immediately replaced.

From four to five hands compose what is called the moulding gang: the shoveller, called a machine tender, a moulder, and from two to three off-bearers. These must all move on regularly, and keep up with the horse; they will make from eight to fourteen thousand bricks per day; the number depending upon the size of the

brick, and the convenience of the works. New moulds should be thoroughly soaked before using. The off-bearers, while the moulds are wet, sand them by dipping sand from the sand box, and shaking it till every part of the inside becomes coated, when each puts an empty mould on the machine directly back of the full one, and between it and the axle, and then takes the full one from the front, in such a manner as to place the side coming last from under the grate next to him. Carrying it to the drying floor, he carefully turns it on the floor, bottom up, leaving the brick in rows running from the kiln-ground towards the machine. He then immediately returns, re-sands his mould, and repeats the operation.

When the business is carried on to much extent, it should, as far as practicable, be arranged into a system: the work should be so arranged that each hand should be kept at the same kind of work; the departments of labour and terms applied are as follows, viz., the teamster, pit-filler, moulder, temperer, off-bearer and yard-hand. The teamster ploughs and scrapes the clay, and does all necessary team work; the pit-filler delivers the clay, and fills the pit; the temperer shovels it into the grinding mill; the moulder makes it, making from five to six brick at each impression; and the off-bearers carry the brick, and lay them on the floor to dry; the yard-hands take care of them from this stage till they are set in the kiln ready to burn. Each man is employed as a suitable hand to do one of the various kinds of work, and expects to be kept at that kind of work through the season, and each becomes skilful in his particular department. It is found that men will do more work,—do it better—with greater ease, and be better satisfied to be kept constantly at one kind of work, than changed from one kind to another; the muscles called into action by a particular kind of work soon become, as the common saying is, seasoned to it, so that they are not easily fatigued,—but change the work, and other muscles are called into action, which soon tire. Brick should not be taken from the yard until dry, and when dry should be taken directly from the yard and set in the kiln. It is very little, if any more work, to set them at once in the kiln, than to carry and bake them (as the practice is at the south) under sheds, and they will dry more thoroughly on the yard, than in *hakes* under a shed, where they cannot receive the sun; and it is about as much work to take them from the shed and put them in the kiln, as from the yard. If room is wanted to keep the moulding gang at work, the yard hands will *hake* them on the yard, running the hakes from the kiln towards the pits. Bricks are then laid between these hakes to dry; this process saves handling, the brick becomes better dried, and the corners and edges less injured than by the other process.

What is called the burning shed, is constructed by setting two rows of posts to stand on each side of the kiln, from 18 to 20 feet apart, ranging so as to accommodate the arches, which will vary according to the length of the brick, leaving five or six arches between the posts; these posts should rise three feet above the kiln; plates should be framed on the top, and connected with iron rods, passing from one plate to the other over the kiln to keep them from spreading by the weight of the roof; rafters placed about six feet apart rest upon these plates, ribs or slates are placed across the rafters on which rests the roof of boards; on either side of these posts, and at a distance of ten or twelve feet therefrom, are set two other rows of posts having plates framed on the top sufficiently high to pass under with teams, &c. These form wings to the main shed, and should be covered permanently. When a kiln is burning, and becomes so hot as to endanger the roof of the main shed, the boards should be slid therefrom on to the wings, and replaced when the kiln is sufficiently cool.

SEASONING OF WOOD.

REPORT *to* H. B. RIDDELL, ESQ., C. S., POST MASTER GENERAL, N. W. P., *on the* ARTIFICIAL SEASONING OF BABOOL WOOD *for Carriage Wheels, &c., by* G. PATON, ESQ., POST MASTER, ALLYGURH, *dated 22nd October* 1849.

SIR,

I have the honor to report to you the result of my experience in seasoning Babool wood, by boiling it in water. I am aware that the process of boiling is not new as a mode of seasoning wood, but I believe it has been generally supposed that it is attended with a diminution of strength, elasticity, and durability, and as I have not found such to be the case, I am of opinion that a knowledge of the fact is of some consequence. When requested to undertake the superintendence of the Mail Cart Establishment on the Grand Trunk Road, in 1842, I found great difficulty in procuring seasoned wood for wheels. Sissoo wood was very high in price, and so scarce, that I could not procure it in sufficient quantity. I was therefore obliged to have recourse to Babool wood, and although plentiful, it was difficult to command a supply of any that had been seasoned by the common process of drying. This led me to have some fresh wood boiled and dried, and I was not a little surprized to find that the wheels, made of the wood by the usual process of seasoning by drying, were worn out, while those that were made of the wood seasoned by boiling, were in an excellent state of preservation, although both had been subjected to the same, or equal degree of tear and wear. The experiment appeared at once conclusive, that boiling did not, as generally supposed, impair the strength, elasticity, and durability, at least of this species of wood; but, on the contrary, preserved and increased those qualities. Subsequent experience has tended to confirm this opinion, and I am inclined to account for the fact by the circumstance of *tannin* existing in, and abounding in, the bark of this wood. By boiling, the woody fibre is deprived of the fluid called the sap, while it is saturated or impregnated with the *tannin*.

The cohesion, and solidity or density of the wood, are increased, and the susceptibility to warp, split, swell or contract by the alternating exposure to heat and cold, dryness and moisture, is diminished by this mode of seasoning, and I attribute all these advantages over the common process of simply drying, to the amalgamation of the *tannin* with the woody fibre.

We have a well known instance of the action of *tannin* on the prepared skins of animals, which renders them, by uniting with gelatines, strong, tough and durable; or converts them into leather. Green wood answers best for boiling, evidently on account of the greater facility with which it parts with its sap or juices, and becomes impregnable with *tannin*. The bark should be more or less fresh, and boiled along with the wood. The length of time in boiling the wood should never exceed twelve hours, otherwise the strength, in place of being increased, might be impaired. After boiling, care should be taken to place the wood for some days under cover, and free from the chance of a current of air. The rainy and cold seasons are most favorable; and advantage should be taken of them.

The average time required for thorough seasoning by boiling, is only four months, whereas, by the slow process of seasoning by the natural action of the atmosphere, it is never less than from two to five years.

Independent, then, of the advantages already enumerated, we have also the important one of economy, to recommend the seasoning by boiling. To carry on the Mail

Carriage, Truck and Waggon establishment now attached to this office, a large amount of capital would have to be expended, for the purpose of having in hand at all times a large supply of dry timber. This speedy process of seasoning is the means of saving the interest of the capital that otherwise would have to be employed. So much do I value *tannin* as a preservative of timber by boiling, that I would venture to throw out a suggestion of an experiment being made with it in our dockyards, where dry-rot has of late been so destructive in our wooden walls. The Oak, like the Babool, has its bark abounding with *tannin*, and if boiled together, the result might be equally important, in speedily seasoning, without impairing the strength, and also of preserving it from the dry-rot. I have observed that the sap-wood, or alburnum of the Babool, is, by boiling, rendered as good as the best wood, and the preservation of it I attribute to the *tannin*. The sap-wood, if left to the natural action of the atmosphere, would be found useless, as it would speedily become soft or friable, as if consumed by a species of insect or dry-rot. The exact nature of dry-rot is, I believe, still an open question, on which there is much diversity of opinion, but whether from the action of the seeds of cryptogamous plants vegetating in timber, the fermentation of the juices, or albuminous parts, or from the consumption of the woody fibre by insects, I feel warranted in recommending the process of seasoning by boiling with *tannin* as a preservation of timber, from the simple observations of its effect in the sap-wood of the Babool tree. In what I have stated, my experience is entirely confirmed to the use of the Babool wood for wheels, for the composition of all the parts of which, viz. the nave, spokes, and fellies, it is equally well adapted. Those pieces are cut out in the rough state, then boiled, and laid out to dry; when thoroughly dried, the rough surface is taken off: and then they are cut of the exact size and shape required. The pieces for naves, before being boiled, are carefully turned according to the size required; after boiling, small holes for the spokes are cut: and then they are placed under cover to dry. When nearly dry (which usually happens under three months) any cracks that appear on the surface are carefully filled with paste, or putty. They are then painted, and placed in the open air or sun. A second coat of paint is usually applied, while they are exposed in the open air; after which they are considered fit for use, and the holes may at any time be enlarged to the size required for the spokes. The proper seasoning of the nave is important, as on it the strength of a wheel chiefly depends.

As a proof of the durability of the wheels, I may mention that the palankeen carriages and trucks, running at the average of 7 or 8 miles in the hour, have passed over the distance of 114,660 miles; while the waggons, travelling at the rate of two miles in the hour, have passed over 50,652 miles.

The former have been in use about five, and the latter about three years and a half, with exposure at all times to the climate; and notwithstanding, the wheels are still quite serviceable. The wheels of the mail-carts, which run upwards of ten miles in the hour, have worn equally well; but I am unable to ascertain exactly the distance over which they have passed. I give a decided preference to the straight or cylindrical wheel, as I am convinced that it is stronger and more durable than the wheel with much dishing. I think the result of the tear and wear of the wheel made here will bear a comparison with the wheels made of the best seasoned materials in any part of India or England.

REPORT ON THE DIFFERENT KINDS OF WOOD, PROCURABLE ON THE LINES OF THE AGRA AND BOMBAY ROAD, AND THE GREAT DECCAN ROAD.

Extract, paragraphs 1 *to* 3, *of a Letter from the* SUPERINTENDING ENGINEER *of the Central Provinces, to the* OFFICIATING SECRETARY *to the* MILITARY BOARD, *Fort William, No.* 352, *dated the* 14*th June* 1851.

1.—I have the honor to inform you that I have, on the 21st ultimo, forwarded, for the purpose of being despatched by steamer from Allahabad, a box containing specimens of wood of such kinds in the neighbourhood of the Agra and Bombay Road as may be deemed fit to be subjected to scrutiny, chemically and otherwise, comparatively with saul and teak, with a view of testing their merits for employment in the construction of Lattice Bridges. A tabular statement accompanies this letter, detailing the nature and description of the wood, where found, and the uses to which they are put by the natives, with such other information as may be deemed necessary to enable a judgment to be passed on their merits.

2.—This communication has reference to the 45th paragraph of my Report on that Road, No. 2078, dated the 24th February 1851; and as there are several localities which I have detailed in that Report, where these bridges might be advantageously employed, the subject is worthy of consideration.

3.—The "muhwa" and "khowra," but especially the former, are abundant, and used for such purposes as show their adaptability to these kinds of bridges; and I have little doubt, but that if seasoned properly, and saturated with the chloride of zinc, or sulphate of copper, would be found a valuable material for the purposes I allude to.

Statement of Timbers, procurable on the Agra and Bombay Road, Great Deccan Road, and Gwalior and Cawnpore Divisions of Public Works.

Name of Wood.	*Where found.*	*Division.*	*Nature and Properties.*	REMARKS.
KHOWRA, ..	(No. V.) Dark color, between Seepree and Indore.	Gwalior ..	Close grained, hard, tough, not liable to bend.	The khowra is used extensively for beams, planks and fellies of wheels, between Ragoogurh and Puchore. Timbers of 20 feet can be obtained only after enquiry, but smaller timbers, of 12 and 15 feet, can be procured easily. Planks, for bridge building, 12 feet in length, by 12 inches in breadth and 3 inches in thickness, will cost, on an average, one rupee each, including all expenses.
SADIR, ..	(No. VIII.) Around Sarungpoor, Augur and Indore.	Ditto	More flexible than muhwa or khowra, and a lighter wood.	This is almost the only wood used for beams around Sarungpoor, Augur and Indore, but as it is a lighter wood, as well as cheaper than the muhwa or khowra, additional stiffness should be obtained at the same expense by increase of scantling.

Statement of Timbers, procurable on the Agra and Bombay Road, Great Deccan Road, and Gwalior and Cawnpore Divisions of Public Works—(continued.)

Name of Wood.	*Where found.*	*Division.*	*Nature and Properties.*	Remarks.
	(No. II.) Seepree and Indore.	Ditto	It is hard, durable, tough, strong and cheap. When freshly cut, bends very much; but a well seasoned timber is almost inflexible.	It is difficult to obtain muhwa timbers of any great length, and when obtained, the timbers are always of small scantling. But 3-inch planks 12 feet long by 10 inches in breadth, more or less, can be procured at an average price of one rupee each,—felling, squaring and carriage included. For bridge purposes I consider the old red muhwa is the best timber procurable along the Bombay road from Seepree to Indore.
Muhwa, ..	In the Budowra, Sirsee, Mow & other Forests.	Agra & Bombay road ..	It is of a tough, and durable nature.	This wood is plentiful. Seasoning in water is advisable. Roof timbers, or kurrees of this wood, have lasted 100 and 150 years. Scantlings varying in diameter from 9″ to 3′ and 4′, and may be purchased from 4 to 6 rupees per tree. The fruit of this tree gives fair annual return to the zemindars; consequently objections may be made to fell trees, length from 15 to 20 feet.
Ditto, ..	Is found all over the southern portion of Bundlekund.	7th, or Cawnpore Division.	Is reckoned the next best wood to saul wood.	Is found in greater or less quantities all over the southern portion of Bundlekund. Average length from 16 to 18 feet, and from 18″ to 14″ in thickness. May sometimes be procured of a larger size than this; and is a good serviceable timber, if properly seasoned, by being left for a couple of months in a running stream. Muhwa timber is used for *chowkuts* of doors, plank doors, wall plates, and principals, &c. in roofing, and for the latter purpose is reckoned the next best wood to saul wood. It would I think answer very well for the large beams in bridges, if it could be preserved from *ghoon*.
Khyre, ..	(No.) Plentiful on the hills & in ravines.	Agra & Bombay road.	Hard and brittle, ..	This wood is plentiful on the hills, and in ravines in most of the forests; and seasoning by placing in a dung hill is recommended. It answers well for uprights, and receives a good polish. Lengths from 12′ to 14′; diameter 8″ to 15″. Frames for hackeries, ploughs, and pivots for sugar mills, are made of this wood, and it may be felled in the forests without purchase-money.

Statement of Timbers, procurable on the Agra and Bombay Road, Great Deccan Road, and Gwalior and Cawnpore Divisions of Public Works.—(continued.)

Name of Wood.	*Where found.*	*Division.*	*Nature and Properties.*	Remarks.
Babool, ..	(No. I.) between Sasram and Gonah, and for miles east and west.	Agra & Bombay Road.	It may be classed as the best sort of wood for trenails. If well seasoned in water, it will neither rot nor *ghoon*.	This description of wood is well known, and generally procurable at most villages between Sasram and Gonah, and for miles east and west; varying in diameter from 3″ to 1½′ and 2′: and may be purchased at 6 annas to 3 and 3½ rupees.
Teak, ..	Between Jubbulpore and Nagpore.	Great, Deccan Road.	This is too well known to need description.	At present much teak of a large scantling cannot be obtained very near the line of road, for the demand for it was so great, and the natives so reckless in the destruction of undersized trees, that in a few years the forests here were likely to be denuded of teak. Fortunately, the Deputy Commissioner reported the circumstance to Government, and in 1847, received orders to prevent the indiscriminate cutting of teak. The young trees abound and look very flourishing, and this forest promises, in a few years, to become a very valuable one.
Tendoo, ..	In the jungles at Mungowah, also in the jungles bordering on the Nagpore Road.	Great Deccan Road.	It has a slight degree of elasticity; should be kept well exposed: if buried will soon be attacked by worms, &c.	It is used for palkee poles, axle trees, &c., and the ebony makes good wheel boxes, and the numerous fancy articles to which it is applied. It weighs per cubic foot 70 lbs.
Ditto, ..	Plentiful in the Forests.	Agra & Bombay Road.	If well seasoned in water, and felled at the close of rains, is durable and tough.	Frame pieces and wooden axles for hackeries are made of this wood, varying in diameter from 6′ to 2′. Readily attacked by *ghoon*, but never rots. Length from 15′ to 18′, and may be felled in the forests without purchasing.
Ditto, ..	In the neighbourhood of Adjegurh and Bisramghat.	7th, or Cawnpore Division.	It resists the effects of water, and does not warp in the sun, or rot.	Grows in considerable quantities. Average length 10 to 12 feet, 4 inches in diameter below, and 3′ above; is a good serviceable timber, when left to season for 3 or 4 years:—should be cut after the rainy season; and is well adapted for parts of wooden bridges. It is procurable in shape of *bullies*, or beams. It is mostly employed by natives in the construction of hackeries and other articles requiring a durable kind of timber.

Statement of Timbers, procurable on the Agra and Bombay Road, Great Deccan Road, and Gwalior and Cawnpore Divisions of Public Works—(continued.)

Name of Wood.	Where found.	Division.	Nature and Properties.	Remarks.
Koa'h, ..	In Budowrah and Sirsee Mow Forests.	Agra & Bombay Road.	If well seasoned in water is elastic and tough.	Hackeries and frames are made of this wood, varying in diameter from 1′ to 1½′. Sometimes rots and ghoons. It may be procured in length from 18′ to 25′ and may be felled in the forests without purchasing. The only expense would be felling, scantling and carting.
Beejah Sal, ..	In the neighbourhood of Mungowah, also in the jungles bordering on the Nagpore road.	Great Deccan Road.	Liable to split, but is very durable, and the least moisture will cause it to throw out stains.	It is much used in house building, particularly where large beams are required, for it combines great lightness with great strength. Now that teak is difficult to be obtained in these jungles, Beejah Sal in a great measure supplies its place. It weighs per cubic foot 66 lbs.
Saj, ...	Ditto ditto.	Ditto ditto.	It is heavy, sinks in water, close-grained and durable.	Grows to a height very straight, and timbers of 50 feet in length and 12 inches square are obtainable. Much used in house building and constructing carts. A cubic foot weighs 55 lbs.
Sessu, ..	Ditto ditto.	Ditto ditto.	Is a handsome close-grained, black, strong and durable wood.	Grows to a considerable size, and is obtainable in timbers 18 feet in length with a scantling of 18″. Out of twelve trees, eleven of them will be of no great use to the cabinet-maker, for the heart of the tree is generally cracked and filled with a kind of petrified resin. The natives use it for toothed combs, also for felloes of wheels, writing desks, &c. Weighs per cubic foot 78 lbs.
Dhangairi, ...	Ditto ditto.	Ditto ditto.	Is a close-grained and very strong wood.	Timbers of 16 feet in length, and 12 inches scantling are obtained with difficulty. I think it rather liable to split. Weighs 69 lbs. per cubic foot.
Pursudh,	On the Sohagee Hills.	Ditto ditto.	Is a dark, very heavy durable, close-grained, and hard wood.	It is used for door frames and trusses; timbers of about 12 feet in length and 9 inches square may be obtained from the trunk of the tree. A cubic foot of this wood, when dry, weighs 102 lbs.

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